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CROATIAN NATIONAL BANK

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Igor Ljubaj, Ana Martinis, Marko Mrkalj

Summary

This paper aims to explore to what degree the Croatian National Bank (the CNB) sterilised capital inflows in the period from 2000 to 2009 by estimating a sterilisation coefficient, and to explore to what degree the central bank's activities in the domestic market spurred additional capital inflows by estimating an offset coefficient. The sterilisation coefficient was estimated through the estimation of the monetary policy reaction function, while the capital-flow equation was used to estimate the offset coefficient. Econometric estimation (2SLS) was used to find the relevant explanatory variables that enabled the estimation of the mentioned coefficients. According to the estimated coefficients it may be concluded that during the period under review the CNB was conducting a policy of strong, but not full sterilisation of foreign inflows. However, by using monetary policy instruments the CNB, to some degree, also indirectly contributed to additional capital inflows. Nevertheless, estimated coefficients indicate that despite the liberalisation of capital flows and their continued strengthening, the central bank managed to preserve the relatively high autonomy and efficiency of its sterilisation policy.

JEL: E52, F41

Keywords: sterilisation coefficient, offset coefficient, capital inflows

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Contents

1 Introduction

The ability to run an efficient monetary policy in an open economy with a fixed exchange rate regime largely depends on the interaction between monetary policy instruments and capital inflows to the country. Capital inflow creates appreciation pressures that are neutralised by the central bank's foreign exchange interventions (i.e. purchases of foreign exchange in the market), with the aim of maintaining exchange rate stability. However, the purchase of foreign exchange results in the increase of international reserves and the increase in money supply, which can build up inflationary pressures thus being in opposition to the central bank's key objective. Therefore, central banks tend to conduct sterilisation policies, estimating that the rise of inflationary pressures in the absence of sterilisation would be detrimental to financial stability and the economy as a whole.

In the circumstances of accelerated involvement in international financial flows and the strong inflow of capital into Central and East European countries, and thus into Croatia, central banks usually were conducting sterilisation policies. In doing so, they were relying on the reserve requirements, on central bank bills or drawing of liquidity from the system through open market operations. In this situation the question that arises is to which degree central banks sterilise foreign exchange interventions or to which degree they neutralise the change in their net foreign assets (international reserves) by changing their net domestic assets, with the aim of managing reserve money. Moreover, an additional question may be asked, which arises from the reaction of the environment to the withdrawal of liquidity by the central bank. Sterilisation curbs money supply and may result in higher interest rates, which can attract new capital inflows from abroad. Additional inflows lead to new appreciation pressures and to the need for new interventions, which can make money supply management difficult and jeopardise the autonomy of the central bank. As a result, a central bank can find itself in a vicious circle where it needs to choose to what extent it wants to use sterilisation policy by taking into account the consequences it might have on future developments. In this context, an analysis of the interdependence of the sterilisation efforts of the central bank and foreign capital flows has an important role in the evaluation of the effects and efficiency of monetary policy.

Analysis of sterilisation policy in the available literature is usually based on the estimation of two coefficients. The first, which is called the sterilisation coefficient, examines the intensity or the degree of sterilisation, i.e. the share of money created by foreign exchange interventions that the central bank neutralises by other monetary policy measures. Second, the estimation of the degree to which this kind of policy spurs additional capital inflows from abroad can be carried out by calculating the so-called offset coefficient.

This paper aims to estimate, for the first time, the said coefficients for Croatia, thus exploring the degree to which the Croatian National Bank sterilised capital inflows in the period from 2000 to 2009 and the degree to which its activities in the domestic market spurred new, additional, capital inflows. The monetary policy

reaction function has been used for the estimation of the sterilisation coefficient in accordance with Cumby and Obstfeld (1983), while the estimation of the offset coefficient is carried out using the capital-flow equation according to the model by Kouri and Porter (1974). Econometric estimation was used to find the group of relevant explanatory variables. This enabled the estimation of the said coefficients with a high significance level.

According to the estimated coefficients it may be concluded that during the period under review the CNB pursued a policy of strong but not full sterilisation of foreign inflows. Nevertheless, by implementing various monetary policy instruments and fulfilling its primary objective, the CNB did indirectly contribute to additional capital inflows. The increase in the level of capital mobility over time did not significantly decrease the efficiency and the autonomy of monetary sterilisation and ample capital inflows were also caused by a series of other factors.

This paper starts with a short description of the main features of capital inflows to Croatia and the central bank's sterilisation policy over the last decade, which is relevant for the topic of this paper. The next section provides the literature-based theoretical framework, the foundation for subsequent coefficient estimation, and this is followed by the description of data and the model, the econometric approach, and interpretation of results. The paper ends with concluding remarks.

2 Capital Inflows and Sterilisation Policy of the CNB

After the end of the banking crisis and economic contraction of the late 1990s, Croatia entered a period of continued strong economic growth spurred by the expansion of domestic consumption and accompanied by strong banking sector development.[1] The favourable economic environment and the liberalisation of capital flows, but also the widening of external imbalances reflected in the increased current account deficit, contributed to the intensification of capital inflows to Croatia. In 2000, capital inflows thus exceeded EUR 3bn. They continued increasing over the years to come, accounting for about 17% of GDP in the period from 2006 to 2008.

Table 1 Capital Inflows to Croatia, in million EUR and %

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009 Q1
Total capital inflows to Croatia	3,062	2,353	3,553	6,047	4,086	3,652	6,589	7,081	7,628	–200
Foreign direct investments (FDI)	837	1,467	1,138	1,762	950	1,468	2,765	3,670	3,353	437
Portfolio investments	793	830	213	746	1,023	–607	–70	411	–354	–572
Other investments	1,431	55	2,202	3,539	2,113	2,790	3,894	3,000	4,629	–65
Share of total capital inflows in GDP	13.2	9.2	12.6	20.1	12.5	10.2	16.9	16.5	16.1	–1.9

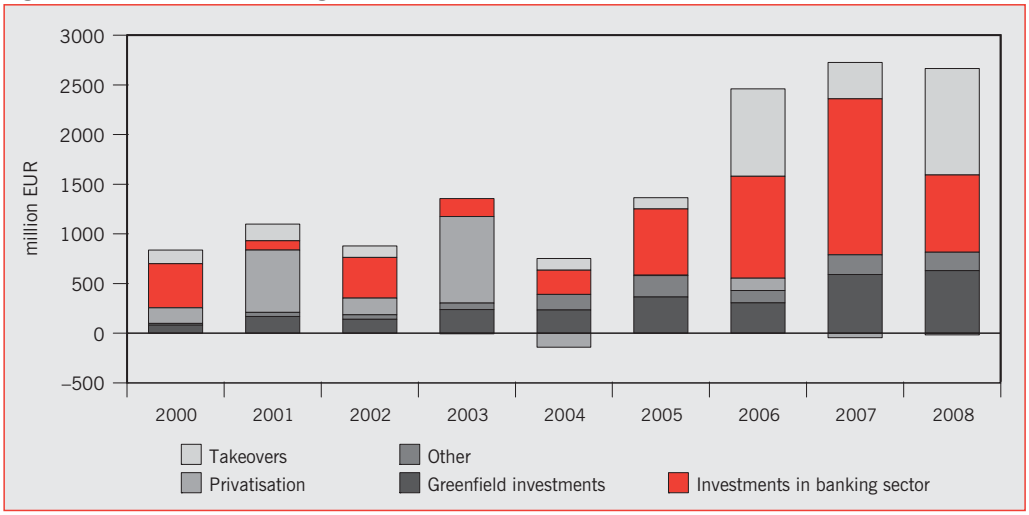
Source: CNB.

1 In the period from 1998 to 2000 several banks failed, which spurred deposit withdrawals from banks and the strengthening of depreciation pressures on the kuna, causing the real GDP to fall by 1.5% in 1999 (Kraft and Jankov, 2005).

The surge in capital inflows to transition countries and thus to Croatia was on the one hand affected by pull factors such as privatisation, financial deregulation, macroeconomic stability, favourable macroeconomic outlook, stable exchange rate and higher interest rates, and on the other hand by favourable global factors, called push factors, such as low interest rates in developed countries, the increase in global liquidity and the entry of multinational banking corporations to Central and East European markets (Ötker-Robe et al., 2007).

In terms of structure of capital inflows, it is clear that over the last decade foreign direct investments and loans from foreign creditors were equally strong. The structure of foreign direct investments (Figure 1) was dominated by inflows to the financial sector, while greenfield investments in the real sector (mostly into the retail sector) accounted for only a small share. In addition, the inflow of equity capital into the banking system gained strength over the last few years, relating primarily to recapitalisations of foreign-owned domestic banks due to the central bank's prudential measures. In addition to the described capital inflows, Croatia also saw a strong inflow of foreign exchange in the form of tourism revenues.

Figure 1 The Structure of Foreign Direct Investments to Croatia



Note: The data refer to direct equity investments and retained earnings.
Source: CNB.

As regards external debt, in the years after gaining access to the international capital market, government external debt increased the most. However, in the period from 2002 to 2006, the banking sector became the primary generator of external debt growth. One of the main factors contributing to rising banking sector borrowing was the surge in bank loans to the private sector (predominantly financed by foreign funds) which was made easier by the fact that the majority of domestic banks are foreign owned (Ötker-Robe et al., 2007).[2]

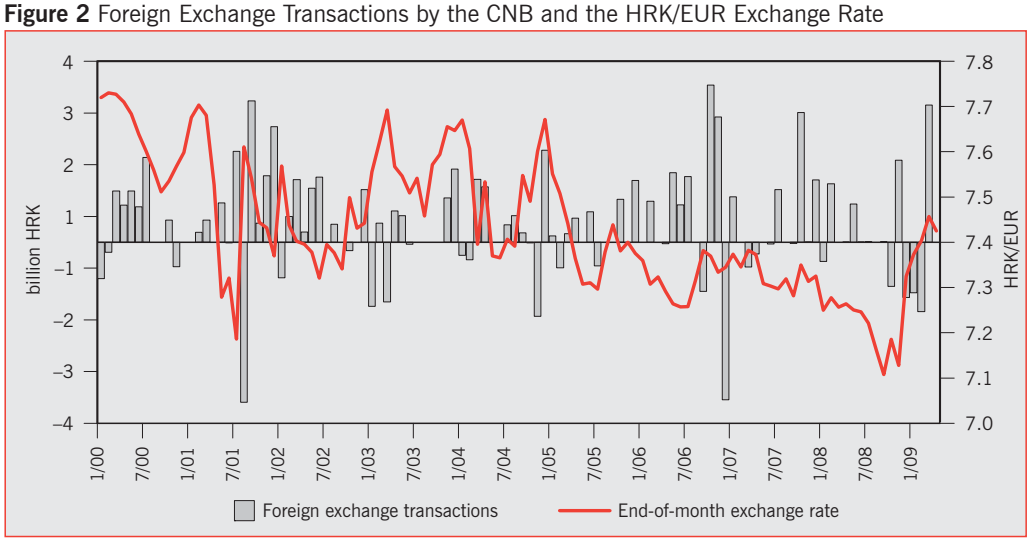
The fast growth of loans contributed to the expansion of consumption, which thus generated an increase in imports and resulted in the continued widening of

2 The consolidation of the banking sector after the financial crisis of 1999 was followed by the entry of foreign banking groups to the market; these have acquired some 90% of domestic banking sector assets.

the current account deficit. To finance the deficit, substantial borrowing of domestic sectors abroad was required. The strong growth in bank foreign borrowing was accompained by the corporate sector; this was most prominent during the years when the domestic banks' credit growth was restricted (in 2003 and from 2007 to 2009). These developments can be attributed to banks themselves that attempted to circumvent the central bank's measures aimed at curbing the growth of foreign borrowing by instructing some of their clients to borrow directly from their parent banks (CNB, 2006).

In addition to the high degree of euroisation of the domestic monetary system and the interdependence between inflationary expectations and exchange rate movements, the described capital inflows to Croatia were among the key factors that determined the manner of implementation of monetary policy instruments. The CNB ensured low and stable inflation primarily through the stabilisation of the domestic currency, with foreign exchange interventions playing the key role. The purchase of foreign exchange (kuna creation) was used to prevent the kuna from appreciating as a result of large capital inflow from abroad. As shown in Figure 2, foreign exchange transactions with commercial banks and the government were dominated by foreign exchange transactions, and this contributed to the central bank's accumulation of foreign exchange reserves. As a result, in the period from January 2000 to April 2009 the overall international reserves of the CNB tripled, totalling EUR 8.9bn.

Figure 2 Foreign Exchange Transactions by the CNB and the HRK/EUR Exchange Rate



Note: Foreign exchange transactions (grey columns) include foreign exchange auctions (interventions) and direct transactions with commercial banks, as well as foreign exchange transactions with the Ministry of Finance. The positive value of foreign exchange transactions represents foreign exchange purchases, i.e. the creation of kuna liquidity by the CNB.

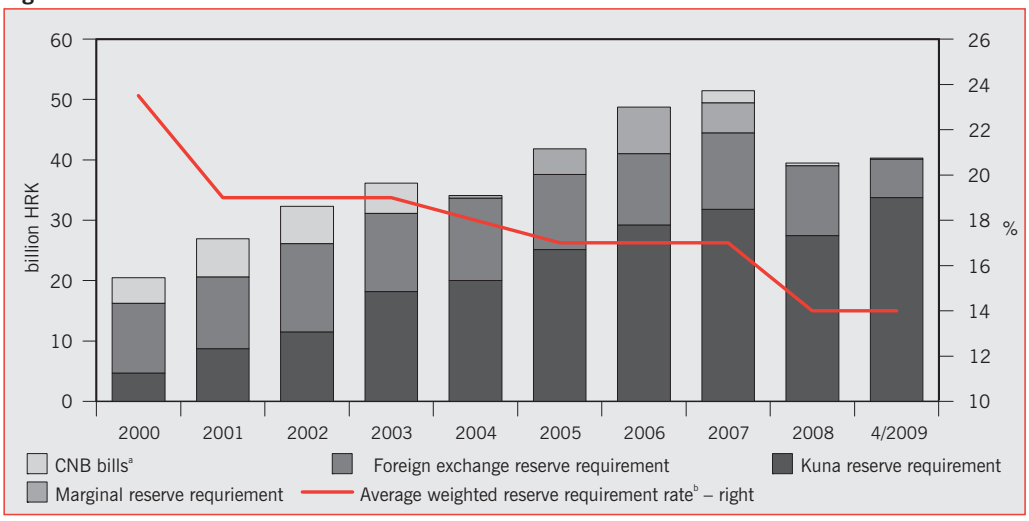
Source: CNB.

Since the supply of foreign currency, coming from strong capital inflows, was exceeding the potential growth of kuna liquidity within which low inflation can be maintained (see Rohatinski, 2004), the CNB was relying intensively on sterilisation instruments. In doing so, the CNB turned less to market instruments (open market operations) and more to administrative measures (reserve requirement,

allocation of foreign exchange reserve requirement in kuna, marginal reserve requirement and minimum required amount of foreign currency claims). The high degree of euroisation of the domestic banking system and monetary policy based on a stable exchange rate largely limit the scope of monetary policy. Because the monetary policy transmission mechanism through the interest rate channel is very weak, the central bank's influence on monetary developments is more efficient through the use of reserve requirements or other administrative measures. The CNB creates the largest share of reserve money by purchasing foreign exchange on the foreign exchange market, while open market operations are primarily used for short-term liquidity management.

Overall, as shown in Figure 3, liquidity sterilised by the CNB in the period from 2000 to the end of 2008 grew steadily despite the fact that the average weighted reserve requirement rate has been declining. There were some changes in the structure of sterilised assets during the period, so from 2000 to 2003 the CNB used CNB bills, while from 2004 to the end of 2008 it introduced the marginal reserve requirement on the growth of foreign debt of commercial banks (at a very high rate of 55%). At the end of 2008, when the global economic and financial crisis spilled over onto the domestic market, threatening to bring foreign inflows to a complete halt, the CNB abolished the marginal reserve requirement (October 2008) and reduced the reserve requirement rate (December 2008), thus releasing substantial liquidity and ensuring uninterrupted financing of domestic sectors. At the beginning of 2009, apart from the change in the structure of the reserve requirement, the overall level of sterilised assets remained almost unchanged.[3]

Figure 3 Sterilisation Instruments of the CNB



[a] Includes purchased voluntary and compulsory CNB bills. [b] Does not include the marginal reserve requirement rate, which totalled 55% for the most part of the period during which it was applied.

Source: CNB.

3 In January 2009, the prescribed share of the foreign exchange reserve requirement calculated in kuna was raised from 50% to 75%, which freed additional foreign exchange liquidity, thus reducing depreciation pressures on the exchange rate of the domestic currency.

In addition to the sterilisation measures shown, one additional specific feature of the monetary instruments should be underlined, although is not depicted in the above figure. Namely, one measure played an important role in maintaining overall foreign exchange liquidity of the monetary system and preventing the surplus supply of foreign exchange, though it is not a sterilisation measure by definition and is not registered as such in the central bank's balance sheet, but actually has a similar effect. This is the minimum required amount of foreign currency claims, by which the CNB obliged banks to maintain a minimum amount of foreign currency claims relative to their overall foreign currency liabilities (both domestic and foreign, including foreign currency-indexed liabilities) on a daily basis.[4] Liquid foreign currency claims make up the liquid foreign exchange assets of banks placed abroad. A measure defined in this way means that every increase in foreign exchange liabilities, in addition to the allocation of the reserve requirement, also requires commercial banks to set aside additional foreign exchange reserves abroad. As a result, this money remains outside the domestic monetary system, as if it were sterilised. Therefore, the level of sterilisation in this paper might be underestimated.

3 Theoretical Framework

The theoretical framework for analysis and interpretation of the relationship between capital inflows, sterilisation and monetary policy efficiency is a combination of two approaches usually found in the literature related to the empirical analysis of this subject. The estimation of the sterilisation coefficient, as in much of the existing research, is based on the estimation of the monetary policy reaction function as in Cumby and Obstfeld (1982). On the other hand, the estimation of the offset coefficient in the literature is mostly based on the theoretical framework set by Kouri and Porter (1974), who derived a model of international capital flows assuming a small open economy with a fixed exchange rate regime.[5]

Cumby and Obstfeld (1982) derived the monetary policy reaction function by assuming that the central bank neutralises (or sterilises) the monetary effects of capital inflows from abroad by changing its domestic (net) assets. Accordingly, the monetary policy reaction function may be written as follows:

$$\Delta NDA = \alpha_1 (CA + K) + \gamma_i' X_i, \qquad (1)$$

where ΔNDA is the change in the central bank's net domestic assets, α_1 is the degree of sterilisation, CA is the current account balance, K is the capital account

4 The Decision on the minimum required amount of foreign currency claims was introduced at the beginning of 2003 at a rate of 35%. The rate was reduced to 32% in February 2005, to 28.5% in May 2008 and to 20.0% in February 2009.

5 A number of new research papers on this topic refer to the basic theoretical frameworks set up in these two papers (e.g. Celasun et al., 1999, Siklos, 2000, Perez Campanero, 1990, Jan et al, 2005, Emir et al., 2000, and Kim, 1995).

balance and X is the vector of other variables that could also affect monetary policy actions.[6] Since, in accordance with the balance of payments, the sum of current and capital account balances ($CA + K$) is equal to the change in the central bank's net foreign assets ΔNFA (which is approximated by the change in international reserves), function (1) may be rewritten as follows:

$$\Delta NDA = \alpha_1 \Delta NFA + \gamma_i' X_i. \qquad (2)$$

This relation is actually a simplified monetary policy reaction function, where the coefficient α_1 indicates the degree of sterilisation and is called the sterilisation coefficient. Its value ranges from minus one to zero. When $\alpha_1 = -1$ sterilisation is complete, which means that by reducing its net domestic assets the central bank completely neutralises the increase in reserve money caused by the growth in the central bank's net foreign assets.[7] In other words, if the central bank purchases foreign exchange through interventions in the foreign exchange market and consequently creates reserve money, while at the same time with other monetary policy instruments (e.g. increase of the reserve requirements) it withdraws all the created money from the market, the change in reserve money will be equal to zero, while the increase in *NFA* will be equal to the reduction in the central bank's *NDA*. However, if the value of the sterilisation coefficient is closer to zero (i.e. if the degree of sterilisation is lower), the reserve money generated by central bank's intervention will not be entirely withdrawn from the market ($\Delta M0 \neq 0$; $\Delta NDA < \Delta NFA$). If $\alpha_1 = 0$ (i.e. if sterilisation is not carried out at all), each net inflow or net outflow of foreign capital will result in an equal change in the domestic money supply.

In contrast to the monetary policy reaction function, the capital-flow equation derived from the Kouri and Porter (1974) model provides another view of the interdependence of capital inflows and monetary policy measures. It enables the estimation of the influence of monetary policy on capital inflows from abroad so that the dependent variable is represented by the change in the central bank's net foreign assets (ΔNFA) as a proxy for capital inflows, while the main explanatory variable is the change in the central bank's net domestic assets (ΔNDA), which reflects the effects of monetary policy. On the right side of the equation there are other exogenous variables which can affect capital inflows and they are represented by vector Z in equation (3). A simplified version of the capital-flow equation, on the basis of which the offset coefficient will be estimated in this paper, is represented in the following relationship:

$$\Delta NFA = \beta_1 \Delta NDA + \delta_j' Z_j, \qquad (3)$$

where parameter β_1 is the offset coefficient and its expected value also ranges

6 For instance, inflation, foreign interest rates, GDP growth, etc.

7 According to the definition arising from the central bank's balance sheet, the change in reserve money ($\Delta M0$) is equal to the sum of the change in the central bank's net domestic and net foreign assets:

$$\Delta M0 = \Delta NDA + \Delta NFA.$$

Accordingly, $\Delta M0 = 0$ only when $\Delta NDA = -\Delta NFA$, i.e. when in the relationship (2) the coefficient $\alpha = -1$.

between minus one and zero. If $\beta_1 = -1$, this means that capital is fully mobile, i.e. that each reduction in *NDA* is compensated by an equal increase in *NFA*, while the supply of money in the system remains unchanged and vice versa. Under such circumstances sterilisation is not effective because the total amount of the decline in the central bank's net domestic assets is replaced by additional foreign exchange inflows in the same amount, and they contribute to the increase in international reserves or *NFA*. This additional inflow then needs to be sterilised again, which creates a vicious circle of rising capital inflows and the need for additional sterilisation (Christensen, 2004). On the other hand, if the value of the offset coefficient is closer to zero, the change in the central bank's net domestic assets affects the overall money supply, which means that the impact of activities undertaken by the central bank partially or fully ''remains'' in the system.

It is clear from the above that the value of the offset coefficient largely depends on capital mobility and the degree of substitution between foreign and domestic assets. Generally, the higher the capital mobility and the better the substitution between the foreign and domestic assets, the lower the degree of control of the central bank over the overall money supply and, consequently, the lower the efficiency of monetary policy (the offset coefficient is closer to the value of –1). On the other hand, a low (absolute) value of the offset coefficient and a high (absolute) value of the sterilisation coefficient usually indicate that the autonomy and efficiency of monetary policy are relatively high (Ouyang at al., 2007).

4 Estimation of Sterilisation and Offset Coefficients

4.1 Data Description

The econometric estimation of sterilisation and offset coefficients was done using monthly data for the period from January 2000 to April 2009. The use of monthly data provides a larger number of observations for the analysis of a relatively short period. In addition, the use of higher frequency data is also justified because equations contain mostly monetary variables, which adapt quickly to changes in the environment (Christensen, 2004). That is, monetary policy reacts to fluctuations of the variables it considers relevant almost on a daily basis (exchange rate, liquidity movements, etc.) and the market quickly responds to monetary policy measures. Therefore, the use, for example, of quarterly data would hide a lot of information on monthly movements. The description of all variables used can be found in Appendix I.

The central bank's foreign assets (*NFA*) and reserve money (*M0*) have initially been taken from the balance sheet of the Croatian National Bank, while the third main variable, the central bank's net domestic assets (*NDA*), has been calculated as the difference between reserve money and net foreign assets. However, in order for the said variables to satisfy theoretical characteristics and to reflect the impact of monetary policy correctly, adjustments are needed.

The first adjustment was carried out so as to exclude exchange rate fluctuations from the central bank's net foreign assets.[8] Since exchange rate movements cause changes in the kuna value of the central bank's net foreign assets, and these changes should not be reflected in the movements of reserve money, the effects of exchange rate changes should be excluded from the movement of the *NFA* variable (Celasun et al., 1999, Pérez Campanero, 1990, Siklos, 2000, Waheed, 2007).

The second adjustment relates to the *NDA* variable. Theory suggests that this variable should reflect all forms of monetary policy impact in the domestic market, i.e. the changes in all instruments by which the central bank withdraws or creates money. Accordingly, the *NDA* variable should, together with the effects of open market operations, also include the impact of changes in the reserve requirement rate, changes in the marginal reserve requirement rate and changes in the balance of purchased CNB bills.

The impact of the change in the reserve requirement was estimated by multiplying the calculation base of the reserve requirement from the initial period and the realised change in the reserve requirement rate.[9] Further, the effect of the purchase of new and repurchase of matured bills has been defined as their change in the central bank's balance sheet. For instance, if the balance of compulsory CNB bills increases (which means that the amount of purchased new bills exceeded the amount of matured bills) the central bank's net domestic assets are reduced by that amount (which corresponds to the withdrawal of reserve money from the system). The developments in adjusted and original series of net domestic assets and net foreign assets are shown in the following figure.

8 The formula for the adjustment of the net foreign assets of the CNB is as follows:

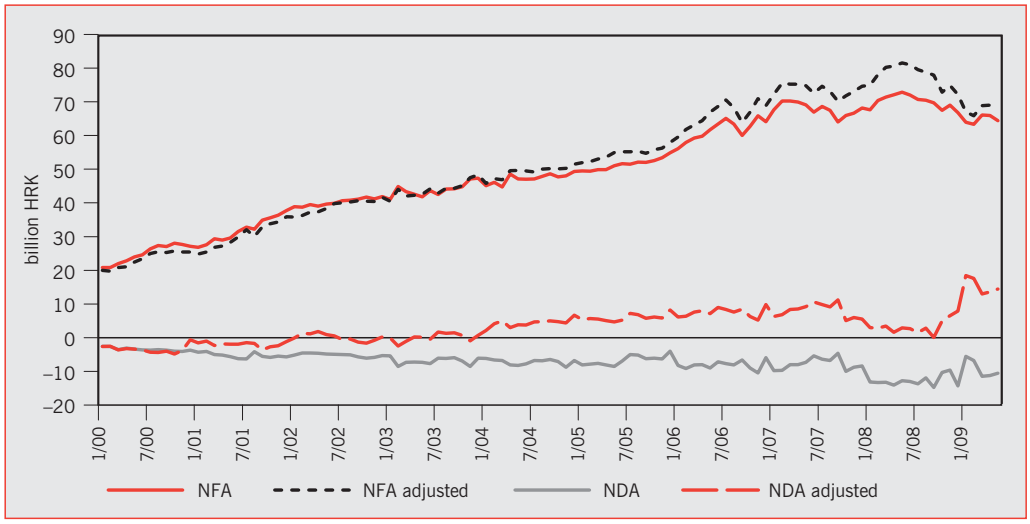
$$\Delta NFA_{adjusted} = \left[\left(\alpha_t \frac{NFA_t}{ER\_eop\_eur_t}\right) - \left(\alpha_{t-1} \frac{NFA_{t-1}}{ER\_eop\_eur_{t-1}}\right)\right] * ER\_av\_eur_t +$$

$$\left[\left(\beta_t \frac{NFA_t}{ER\_eop\_usd_t}\right) - \left(\beta_{t-1} \frac{NFA_{t-1}}{ER\_eop\_usd_{t-1}}\right)\right] * ER\_av\_usd_t,$$

where: α_t = the share of euros in the central bank's NFA, β_t = the share of dollars in the central bank's NFA ($\alpha_t+\beta_t=1$), ER_av_eur = the average monthly exchange rate of the kuna against the euro, ER_eop_eur = end-of-month kuna exchange rate against the euro, ER_av_usd = the average monthly kuna exchange rate against the US dollar, ER_eop_usd = end-of-month kuna exchange rate against the dollar. The adjustment method has been taken over from the European Central Bank (Handbook for the Compilation of Flows Statistics on the MFI Balance Sheet, February, 2006).

9 Adjustment of the *NDA* series for changes in the reserve requirement rate has been carried out in accordance with the method applied in Cumby and Obstfeld (1981), Siklos (2000) and Waheed (2007), and the adjustment for the changes in marginal reserve requirement has been done in the same manner.

Figure 4 Net Domestic and Net Foreign Assets of the CNB



Note: The NFA (net foreign assets of the CNB) has been adjusted for exchange rate changes (adjusted values), while the NDA (net domestic assets of the CNB) has been adjusted not only for exchange rate changes but also for all changes in reserve requirement rates and changes of CNB bills.
Sources: CNB and authors' calculations.

Finally, in order to exclude the increase in the variance of nominal ΔNDA and ΔNFA series over time, ΔNDA and ΔNFA have been scaled by reserve money from the previous period ($M0_{t-1}$).[10]

In addition to the mentioned series, a set of control variables used in the monetary policy reaction function is assumed to influence monetary policy actions. The change in the money multiplier is chosen as a variable that represents a connection between the changes in reserve money and the broadest money (M4) and thus serves as the indicator of the overall impact of creating or withdrawing reserve money.[11] Further, the industrial production was chosen as the variable that describes the movement of economic activity since the real gross domestic product data do not exist at a monthly level and, moreover, it has been shown that industrial production approximates well the overall economic activity.[12] The interest rate on T-bills of the Ministry of Finance with six-month maturity (*TZ-182*) has been used as a measure of interest rates in the domestic financial market. This interest rate has been chosen because these T-bills were the only ones regularly traded during the period under review (along with bills maturing in 91 days),[13] and their average balance was several times higher than the balance of three-month T-bills.[14]

10 Pérez Campanero (1990), Mastropasqua, Micossi and Rinaldi (1988), and Cavoli and Rajan (2005) also divided the NDA and NFA variables with M0t-1. Christensen also applied a similar scaling process (2004), dividing the said variables by M1, while Ouyang et al. (2007) used GDP to scale variables ΔNFA and ΔNDA.

11 The money multiplier is defined as the ratio of total liquid assets (*M4*) to reserve money (*M0*).

12 The central bank uses this approach when carrying out flash GDP estimations based on factor analysis of high frequency data. The monthly industrial production data give the most important contribution to the quarterly GDP estimates despite the relatively low share of the industrial sector in GDP.

13 As for other possible indicators of domestic interest rate movements, the literature often uses overnight interest rates in the interbank market. However, they have not been used in this case due to their extreme volatility over some periods.

14 In addition, the movement of T-bill interest rates with maturity in 3, 6 or 12 months is highly correlated so it may be assumed that each of the said interest rates would be an equally good indicator of interest rate movements in the domestic financial market.

Control variables used in the capital-flow equation are the factors that motivate capital inflow to the country (Ouyang et al., 2007). The nominal exchange rate of the kuna against the euro is included in the equation because this variable is the nominal anchor of the CNB monetary policy. Therefore it is logical to expect that its movement could significantly affect the movements in central bank's *NFA*. In addition to the exchange rate, the capital-flow equation also includes the money multiplier and public debt. The money multiplier is included in both equations because the central bank may react to excessive monetary expansion both with operations in the foreign exchange market (i.e. change in its net foreign assets) and by using other monetary policy instruments (i.e. change in its net domestic assets). As for public debt, this variable is included in the model as an indicator of the character of fiscal policy and as such enables an overview of the interaction between fiscal and monetary policy. Public debt growth may spur additional capital inflows if the government borrows directly in the foreign market, but also indirectly, if the government, for example, is financed by domestic banks that raise the necessary funds abroad, as was the case in Croatia at several occasions.

Most variables used in the equations are log-first-difference form (except for interest rates, which are only differenced). Stationarity of the time series was tested using Augmented Dickey-Fuller and Phillips-Perron tests, and the results are given in Appendix II. The tests have shown that the series used in the models are stationary with a 1% significance level and can as such be used in the estimation of equations under the ordinary least squares (OLS) method and the two-stage least squares (2SLS) method.

4.2 Model

Based on the theoretical framework shown in the third chapter, in order to estimate sterilisation and offset coefficients, an econometric estimation of the following equations has been carried out:

(a) monetary policy reaction function:

$$\Delta NDA_t = \alpha_0 + \alpha_1 \Delta NFA_t + \alpha_2 \Delta \log MM4_t + \alpha_3 \Delta \log IND\_PR_t + \alpha_4 \Delta TZ\_182_t + u_t, \quad (4)$$

where a dependent variable is the central bank's net domestic assets (*NDA*), while independent variables are the central bank's net foreign assets (*NFA*), the money multiplier (*MM4*), industrial production (*IND_PR*) and interest rate on MoF T-bills with six-month maturity (*TZ_182*). In the equation shown, the coefficient α_1 is the sterilisation coefficient.

(b) capital-flow equation:

$$\Delta NFA_t = \beta_0 + \beta_1 \Delta NDA_t + \beta_2 \Delta \log MM4_t + \beta_3 \Delta \log PUB\_DEB_t + \beta_4 \Delta \log HRK\_EUR_t + y_t, \quad (5)$$

where the central bank's net foreign assets is the dependent variable (*NFA*), while

the independent variables of the model are the central bank's net domestic assets (*NDA*), the money multiplier (*MM4*), general government public debt (*PUB_DEB*) and the nominal exchange rate of the kuna against the euro (*HRK_EUR*). In the shown equation the coefficient β_1 is the offset coefficient.

When estimating the said equations it should be taken into account that in the capital-flow equation the theory indicates the problem of the endogeneity of the explanatory variable *NDA*. That is, if the central bank systematically sterilises capital inflows from abroad, the change in *NDA* may be correlated with the residuals in the equation that explains the movement of *NFA* or in the capital-flow equation (Emir et al., 2000). In other words, in case when the central bank is implementing a sterilisation policy, its activities (which are reflected in the movement of the *NDA* variable) will surely depend on capital inflow dynamics, and that means that *NDA* will depend on the movement of the central bank's *NFA*. Accordingly, there is the question of the possible endogeneity of the explanatory *NFA* variable in the monetary policy reaction function. If the endogeneity problem of explanatory variables really exists, the estimation of the said equation under the ordinary least squares method will be biased and inconsistent, as warned by Kouri and Porter (1974) and Obstfeld (1982) in their papers.

The Hausman endogeneity test has been carried out in order to check the endogeneity of the *NFA* variable in the monetary policy reaction function and of the *NDA* variable in the capital flow equation (the test procedure and results are given in Appendix IV below). Although the results of the Hausman test do not indicate that any of the two tested variables has an endogeneity problem, due to theoretical implications the two-stage least squares (*2SLS*) method will be applied for the estimation of both equations.[15] (For the purpose of result comparison, Appendix V provides the estimation of the equation using the ordinary least squares method.)

In some papers the monetary policy reaction function and the capital-flow equation are estimated by using *VAR* models (e.g. Waheed, 2007; Cavoli and Rajan, 2005; Moreno, 1996 and Christensen, 2004). However, a disadvantage of this method is that it only estimates the impact of the change in regressors on the dependent variable with a time lag, while the *2SLS* method also enables the estimation of the current impact of the regressor on the dependent variable (i.e., within the same month if one is speaking about monthly time series). Since in the case of Croatia it is assumed that there is a significant link between variables observed within the same month, due to the availability of high frequency data on monetary and exchange rate movements, as well as due to the recent experience, which confirms the promptness of the monetary policy reaction to the movement of factors relevant for its implementation (e.g. exchange rate volatility, strong inflows of foreign capital), the use of the *2SLS* method might be more appropriate than the use of the *VAR* model.[16]

15 In line with Obstfeld (1982).

16 The CNB usually reacts to the movements of main reference variables within the same month and in some cases even within the same day, either by preventing the excessive exchange rate volatility or appreciation pressures arising from capital inflows (especially in the case of extremely large capital inflows from abroad,

The two-stage least squares (2SLS) method requires the selection of instrumental variables to replace endogenous variables. The theory does not precisely say which instruments should be used in the models analysed here, but from the econometric point of view it is necessary that they meet the condition of being correlated with the explanatory endogenous variable and uncorrelated with the residuals from the estimated model. The change in the nominal exchange rate of the kuna against the euro was chosen as the instrumental variable in the monetary policy reaction function, while in the capital-flow equation the change in total bank placements to domestic sectors was used as the instrument.

The economic explanation of the choice of the exchange rate as the instrument for the *NFA* of the CNB was based on the fact that the exchange rate of the kuna against the euro is the nominal anchor of monetary policy in Croatia. The central bank maintains the stability of the exchange rate almost entirely through foreign exchange interventions, which in turn have a direct impact on the change in the foreign exchange reserves of the CNB (the *NFA* variable). Therefore it is considered that, from the economic point of view, the changes in the exchange rate of the kuna against the euro are well correlated with the movements of the central bank's *NFA* variable.[17]

The choice of banks' placements to domestic sectors as the instrument in the second equation is based on the fact that the central bank, in conducting domestic monetary policy, has taken into account the trends in banks' credit activity and has adjusted its set of instruments to be able to influence the movements of placements. Thus, several changes in monetary policy instruments (the reserve requirement, marginal reserve requirement, CNB bills, etc.) have been adopted by the CNB to limit banks' lending to the private sector as well as to release liquidity for easier financing of the government.[18] Since the very construction of the *NDA* variable is such as to outline all changes in monetary policy instruments, *NDA* movements could be closely linked with the movement of total placements.[19]

The estimated equations have been tested for the presence of heteroscedasticity, using the White test, and for autocorrelation, using the Lagrange multiplier test (LM test). The results of these tests indicate the presence of heteroscedasticity and serial correlation of residuals in the capital-flow equation so variances have been corrected with Newey-West correction method. In contrast, in the monetary policy

for instance, arising from privatisation or takeovers of large domestic companies, foreign bond issues, etc.). The majority of relevant data on monetary developments is collected on a 10-day basis, and consolidated data for the banking sector are available some seven working days after the end of a 10-day period (which means in the same month). In addition, data on reserve money and the balance sheet of the CNB are available daily, as well as data on developments in the foreign exchange market and the money market (i.e. exchange rate, liquidity developments, overnight interest rates, etc.).

17 The results of the test of overidentifying restrictions indicate that the selected instrument is exogenous.

18 Data confirm that only a part of placements growth could have been financed by foreign funds. In the period from 2000 to April 2009 total bank placements to all domestic sectors went up by HRK 210bn. At the same time, banks' foreign debt grew by HRK 61bn, while domestic sources of funds in the form of savings and time deposits went up by HRK 127bn. Thus, the growth of domestic sources of funds was double compared to the growth of foreign sources of funds.

19 In addition to the above, the instrument satisfies statistical conditions related to correlation and, the chosen instrument in the first equation, the test of overidentifying restrictions indicates that the selected instrument is exogenous.

reaction function the zero hypothesis on the homoscedasticity of the residuals and the hypothesis on no serial correlation between residuals cannot be rejected.

4.3 Results

The results of the estimation of the monetary policy reaction function in Table 2 show that the estimated sterilisation coefficient in the period from February 2000 to April 2009 was –0.81.

The estimated coefficient confirms that the Croatian National Bank did not implement policy of complete sterilisation of capital inflows during the period (in which case the sterilisation coefficient would have equalled –1). However, its relatively high value indicates the central bank's commitment to the sterilisation of the large part of capital inflows from abroad. This result is in line with the actual use of monetary policy instruments because over the past years the central bank created reserve money mostly through foreign exchange interventions (purchase of foreign currency and creation of kuna liquidity), while sterilisation was to the greatest extent carried out by imposing a high reserve requirement rate.

As for the coefficients relating to other independent variables in the monetary policy reaction function, the results are in line with expectations and are statistically significant. Higher money multiplication (faster growth of total liquid assets relative to reserve money) implies a more restrictive management of money supply, so the negative, as expected, value of the estimated coefficient means that the CNB under the conditions of faster growth of money reduced its net domestic assets, which was in line with the counter-inflationary objective of monetary policy. The coefficient for the change in domestic interest rate (the interest rate on the six-month T-bills) is also negative; this can mean that higher domestic interest rates, which induce higher capital inflows, require stronger sterilisation in the sense of reducing the central bank's net domestic assets.

Table 2 Results of the Estimated Monetary Policy Reaction Equation for the Estimation of Sterilisation Coefficient

Dependent variable: Δ*NDA*		
Method: Two-Stage Least Squares		
Sample: February 2000 – April 2009		
No. of observations: 111		
Instrumental variable: Δlog *HRK_EUR*		
Variable	**Coefficient**	**T-statistics**
Const.	0.0102[a]	2.7255
Δ*NFA*	–0.8089[a]	–2.8167
Δlog *MM*4	–0.4012[a]	–6.2069
Δlog *IND_PR*	0.1746[b]	2.0674
Δ*TZ*_182	–0.0117[b]	–2.2089
R^2	0.5547	
Adjusted R^2	0.5379	
F-statistics	12.9246	
Probability (F-statistics)	0.0000	

[a] and [b] indicate the significance level of 1% and 5%.
Source: Authors' calculations.

The only positive coefficient is that relating to the variable representing real economic activity in Croatia – industrial production. This relationship is in line with expectations since stronger economic activity requires a larger volume of money and transactions. This confirms that the average positive growth of the domestic economy in the period from 2000 to the beginning of 2009, in addition to the sterilisation of a certain share of inflows, was accompanied by monetary expansion, but the creation of reserve money did not jeopardise the central bank's main objective of maintaining price stability. During the periods of higher inflation rates, (i.e. 2008), inflation was a consequence of external factors (the growth of oil prices and agriculture products), and not of a more substantial creation of base money.

For the purpose of verifying model robustness, in addition to the described variables a whole set of other variables has been tested in the equation that could be significant for monetary policy and that are used in similar analyses in the literature. However, their inclusion has not contributed to the model quality and has proved statistically insignificant. The following variables have been tested: the nominal and real effective kuna exchange rate, the change in consumer price index, foreign interest rate (six-month EURIBOR), interest rate differential (the difference between the domestic and foreign interest rate), and the change in general government public debt and the central government budget balance.

According to the results of the estimated capital flow equation presented in Table 3, the value of the offset coefficient is –0.48. This result indicates that the central bank's sterilisation policy, which is reflected in the reduction of net domestic assets and withdrawal of reserve money through the reserve requirement instrument or open market operations, led only partially to additional capital inflows and ultimately to the increase in the central bank's net foreign assets. As mentioned earlier, if the coefficient amounted to –1, this would indicate the complete inefficiency of the central bank's sterilisation policy, while a coefficient equalling zero would mean that measures undertaken in the domestic market did not result in additional inflows.

Table 3 Results of the Estimated Capital-Flow Equation for the Estimation of Offset Coefficient

Dependent variable: Δ*NFA*		
Method: Two-Stage Least Squares		
Sample: February 2000 – April 2009		
No. of observations: 111		
Instrumental variable: Δ*PLAS*		
Variable	**Coefficient**	**T-statistics**
Const.	0.0093[a]	3.4367
Δ*NDA*	–0.4801[a]	–2.7909
Δlog *MM4*	–0.2833[a]	–5.7995
Δlog *PUB_DEB*	0.3202[b]	2.5662
Δlog *HRK_EUR*	–0.9316[a]	–3.1608
R^2	0.5114	
Adjusted R^2	0.4929	
F-statistics	13.3796	
Probability (F-statistics)	0.0000	

[a] and [b] indicate significance level of 1% and 5%.
Note: The potential autocorrelation and heteroscedasticity problems have been solved by applying the Newey-West procedure for the calculation of the standard errors.
Source: Authors' calculations.

Although on the basis of the estimated offset coefficient it may be concluded that some of the effects of the central bank's sterilisation policy were neutralised by the additional capital inflows, if we take into account the domestic and international macroeconomic circumstances in which the CNB operated, the effectiveness of the sterilisation policy may be assessed as satisfactory. Namely, many factors, such as stable macroeconomic environment, transition and convergence processes, liberalisation of capital flows, trade deficit which induces external debt growth, a long period of low interest rates in developed countries, the growth of global liquidity, etc., spurred capital mobility, which, as stated by Ouyang et al. (2007), reduces the effectiveness of sterilisation.

What is more important in the estimation of the offset coefficient is its notably lower value relative to the estimated sterilisation coefficient. This indicates a relatively high degree of monetary policy independence in neutralising capital inflows (Ouyang et al. 2007).

Same as in the first equation, other explanatory variables, expected to be capable of affecting capital inflows from abroad and used in the literature have been included in the capital-flow equation. Those that proved statistically significant are shown in Table 3.

The coefficient for the variable that can be found in both equations, the rate of change of the money multiplier, again has the expected sign and indicates a negative relation between money multiplication and the central bank's net foreign assets (which are the indicator of capital inflows from abroad). This result is in line with the theory under which higher money multiplication contributes to the growth of liquid assets and consequently to a fall in interest rates, which should lead to the reduction in capital inflows from abroad.

The estimated coefficient for the percentage change in the kuna exchange rate against the euro appropriately reflects the central bank's exchange rate policy, especially if it is taken into account that the CNB relies on foreign exchange interventions to maintain the exchange rate stability. The depreciation of the exchange rate of the domestic currency against the euro (the rise in *EUR_HRK* variable) will force the central bank to sell foreign exchange, i.e. reduce its net foreign assets, which means spending its international reserves. Similarly, prevention of exchange rate appreciation (decline of the *EUR_HRK* variable) requires an intervention from the central bank in the form of foreign exchange purchase, thus increasing the central bank's net foreign assets.

The total general government debt (*PUB_DEB*), which includes both general government domestic and foreign liabilities, is an indicator of the character of fiscal policy in the capital-flow equation, and has been shown to have a positive influence on the foreign capital inflow, i.e. the growth of the central bank's net foreign assets. This indicates that monetary policy was countercyclical under the conditions of growing general government debt. This confirmed that, during the period of fiscal expansion and deficit financed by government borrowing, the CNB was accumulating foreign exchange reserves (i.e. was neutralising capital inflows by increasing net foreign assets), which provided leeway for reacting under the

conditions of slower economic growth and limited inflow of capital from abroad. These efforts proved justified in view of the events of late 2008 and early 2009.

Comparison of the results described with results obtained by other research is difficult because the reference literature uses a whole array of different economic techniques to estimate sterilisation and offset coefficients.[20] Furthermore, the time span of the existing research and additional independent variables in the models also differ. Nevertheless, it is noteworthy and can be seen in this paper that the values of the sterilisation coefficient usually exceed the values of the offset coefficient, which may indicate that central banks in the countries covered by the studies were relatively successful in sterilising capital inflows since their activities only partially induced additional inflow of foreign funds.

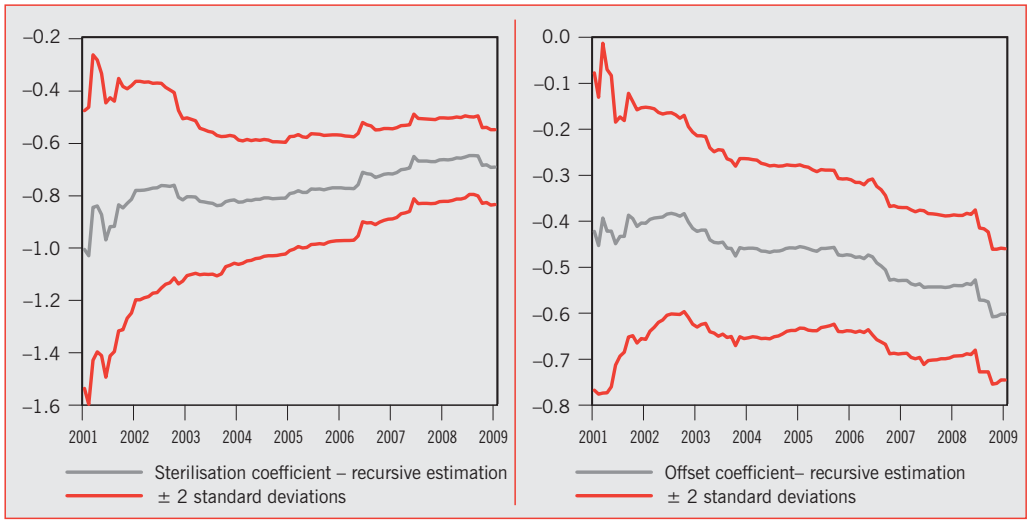
At the same time, it should be noted that, despite such results, the efficiency of sterilisation and especially the efficiency of foreign exchange interventions depend on many other macroeconomic and financial conditions in the market.[21] According to Disyatat and Galati (2005), the efficiency of foreign exchange interventions (i.e. conversion of capital inflows) is most often measured by the extent to which they have been sterilised, i.e. only their impact on reserve money is quantified. In practice, however, it is much more important how interventions might impact interest rates, which should be taken into account when evaluating the effectiveness of central banks' sterilisation policies.

4.4 Recursive Estimation

The changes in estimated coefficients over time can be analysed by applying the recursive estimation method.[22] The results of recursive estimation of sterilisation and offset coefficients are shown in Figure 5. The lines representing the dynamic estimate of the said coefficients are drawn so that the initial value of the series is estimated on the basis of the sample for the period from February 2000 to February 2001, while other data were obtained by gradually adding one observation after another until the last observation in the sample was reached, i.e. until April 2009. It should be pointed out, however, that the reliability of coefficients estimated in this way is lower in the first part of the period under review due to the lower number of observations used to calculate their values.

20 Results of the sterilisation coefficient and offset coefficient estimations in selected research, along with the estimation method, country and time span, are shown in Appendix III.
21 For a more detailed discussion see Sarno and Taylor (2001) and Mihaljek (2005).
22 Due to technical limitations the recursive estimation of coefficients was calculated based on the ordinary least squares method.

Figure 5 Recursive Estimation of Sterilisation and Offset Coefficients



Source: Authors' calculations.

Recursive estimation of sterilisation coefficient showed that in the first part of the period under review, the central bank sterilised almost the entire inflow of capital from abroad (the sterilisation coefficient was close to –1). Then, in the period from 2002 to mid-2006 the coefficient was fairly stable at the level of about –0.8, while until the end of the sample the degree of sterilisation was gradually reduced to the level of –0.69. These results were in line with expectations because in the first part of the period under review, the central bank carried out sterilisation by imposing a high reserve requirement rate and purchase of CNB bills (until 2004), while in the second part of the analysed period a whole array of other monetary policy instruments and measures was introduced, such as, for example, the regular weekly reverse repo auctions, which provided for a more flexible management of kuna and foreign exchange liquidity.[23]

The recursively estimated offset coefficient was fairly stable during the entire period under review, declining gradually to –0.4 during 2001 and 2002, to some –0.53 in 2007 and for the most part of 2008. The fact that the offset coefficient, despite the liberalisation of capital flows and continued strengthening of foreign capital inflows during the past nine years, did not get close to the margin value of –1 confirms that the central bank managed to maintain the autonomy and efficiency of its sterilisation policy. This can, among other things, surely be attributed to the unconventional monetary policy measures implemented in the last few years that were aimed at mitigating the country's external imbalances, limiting banks' excessive foreign debt (primarily marginal reserve requirement and minimum required foreign currency claims) and the forementioned introduction of open market operations.

However, the spillover of the financial crisis to the domestic market has largely changed the circumstances and challenges faced by the monetary policy so it

23 The framework for open market operations was introduced in 2005.

forced an adjustment of the monetary policy character and instruments, which consequently determined the movements of offset coefficient. As seen in Figure 5, as of October 2008, the offset coefficient dropped sharply and remained at that level until the end of the period under review. This confirms that the central bank, by relaxing the monetary policy, successfully spurred inflow of foreign assets at the time when refinancing of foreign liabilities was extremely difficult. This was primarily related to the abolishment of the marginal reserve requirement by which the CNB made bank borrowing abroad ''cheaper''; and it proved crucial for the country's foreign currency liquidity in circumstances of restricted access to foreign capital. Ensuring capital inflow from abroad greatly contributed to the mitigation of the negative impact of the global financial crisis on the stability of the domestic financial system.

5 Conclusion

The estimation of sterilisation and offset coefficients for the period from January 2000 to April 2009 confirmed that during this period the CNB conducted a policy of strong but not full sterilisation of inflows from abroad. At the same time, by using monetary policy instruments, the CNB to a certain degree indirectly contributed to additional capital inflows. It is noteworthy that the increase in the degree of capital mobility over time did not significantly reduce the efficiency of monetary sterilisation, while strong capital inflows were generated due to a whole array of other factors, such as stable macroeconomic environment, economic growth, openness of the country, liberalisation and the trade deficit, which induced the growth of foreign debt, and so on. The lower value of the offset coefficient compared to the sterilisation coefficient indicates a certain degree of independence of monetary policy in neutralising capital inflows.

The recursive estimation of coefficients showed that during the period under review the central bank was reducing the sterilisation coefficient, while at the end of the period, during the spillover of the global financial crisis onto domestic trends, it contributed to the continuation of the capital inflow through a series of changes in monetary policy instruments. Overall, the results confirmed that despite the vigorous inflow of capital over the past ten years, the CNB, with its policy of maintaining exchange rate stability through foreign interventions, sterilisation instruments and other unconventional measures,[24] successfully controlled the expansion of the money supply and thus achieved its primary objective, maintaining relatively low inflation.

Furthermore, although econometric limitations make it difficult to find a group of appropriate explanatory variables which enable an adequate estimation of the

24 The mandatory purchase of CNB bills due to excessive growth of bank loans, and the marginal reserve requirement.

said coefficients within the framework of the monetary policy reaction function and the capital-flow function, parameters were estimated through a series of tests which, in addition to the sterilisation and offset coefficients, provided an additional view of the CNB's operation over the previous years. Results indicate that the CNB reacted to higher monetary multiplication with more restrictive management of the money supply (reducing net domestic assets and net foreign assets, i.e. selling foreign exchange in the market). Similarly, it was shown that the increase in domestic interest rates also required higher sterilisation by the central bank.

On the other hand, the estimated coefficients show that the growth in economic activity was accompanied by appropriate monetary expansion. In addition, it was confirmed that exchange rate depreciation requires the spending of international reserves. Fiscal expansion, however, that is the increase in total public debt, was accompanied by the accumulation of foreign exchange reserves (neutralising capital inflows by increasing the CNB's net foreign assets).

Due to the strong contraction of economic activity in Croatia and the slowdown of capital inflows from abroad in 2009, and considering the uncertainty of macroeconomic developments as well as possible changes in capital flow trends in the upcoming period, the monitoring of sterilisation and offset coefficients will continue to be useful in assessing the character and effects of sterilisation policy under dramatically altered conditions.

6 Appendices

Appendix I Description of Variables Used in Estimated Equations

Variable code	Variable description	Variable calculation	Source
ΔNFA	*Change in net foreign assets of the CNB, scaled by reserve money from the previous period*	$(NFA_t - NFA_{t-1})$/Reserve money$(MO)_{t-1}$	CNB
ΔNDA	*Change in net domestic assets of the CNB, scaled by reserve money from the previous period, where net domestic assets are calculated as reserve money minus net foreign assets of the CNB*	$(NDA_t - NDA_{t-1})$/Reserve money$(MO)_{t-1}$	CNB
$\Delta \log MM4$	*Percentage change of the money multiplier M4, where the money multiplier is calculated as the ratio of total liquid assets (M4) and reserve money (M0)*	$\log(MM4)_t - \log(MM4)_{t-1}$	CNB
$\Delta \log IND\_PR$	*Percentage change of the industrial production index*	$\log(IND\_PR)_t - \log(IND\_PR)_{t-1}$	CBS
ΔTZ_182	*Change in interest rate on the MoF T-bills with 6-month maturity (182 days)*	$TZ\_182_t - TZ\_182_{t-1}$	MoF
$\Delta \log PUB\_DEB$	*Percentage change of the general government debt*	$\log(PUB\_DEB)_t - \log(PUB\_DEB)_{t-1}$	CNB
$\Delta \log HRK\_EUR$	*Percentage change of the average monthly HRK/EUR exchange rate*	$\log(HRK\_EUR)_t - \log(HRK\_EUR)_{t-1}$	CNB
$\Delta PLAS$	*Change in total bank placements to domestic sectors scaled by reserve money from the previous period*	$(PLAS_t - PLAS_{t-1})$/Reserve money$(MO)_{t-1}$	CNB

Appendix II Testing the Stationarity of Variables

Variable	ADF		PP	
	T-statistic		T-statistic	
	Intercept	Intercept and trend	Intercept	Intercept and trend
Δ*NFA*	–3.935[a]	–12.101[a]	–10.987[a]	–12.002[a]
Δ*NDA*	–11.945[a]	–11.896[a]	–12.512[a]	–12.438[a]
log *MM4*	–1.325	–1.183	–1.469	–3.322[c]
Δlog *MM4*	–7.258[a]	–7.298[a]	–20.593[a]	–21.898[a]
log *IND_PR*	–1.281	–2.481	–1.666	–3.482[b]
Δlog *IND_PR*	–14.630[a]	–14.599[a]	–16.813[a]	–17.425[a]
TZ_182	–2.878[c]	–1.875	–2.769[c]	–1.555
Δ*TZ_182*	–8.568[a]	–8.049[a]	–8.536[a]	–9.092[a]
log *HRK_EUR*	–3.533[a]	–4.558[a]	–2.428	–2.782
Δlog *HRK_EUR*	–6.118[a]	–6.127[a]	–7.745[a]	–7.856[a]
log *PUB_DEB*	–2.886[c]	–3.106	–2.994[b]	–3.113[c]
Δlog *PUB_DEB*	–10.195[a]	–10.490[a]	–10.228[a]	–10.491[a]
Δ*PLAS*	–10.570[a]	–10.649[a]	–10.576[a]	–10.649[a]

[a], [b], [c] indicate that the assumption of non-stationarity may be rejected at the significance level of 1%, 5% and 10%.
ADF = Augmented Dickey-Fuller test
PP = Phillips-Perron test

Appendix III Review of Selected Studies

Author	Method	Country	Period	Sterilisation coefficient	Offset coefficient
Kouri and Porter (1974)	OLS	Germany	1960–1970	–	–0.77
		Netherlands	1960–1970	–	–0.59
		Australia	1961–1972	–	–0.47
		Italy	1960–1970	–	–0.43
Obstfeld (1982)	OLS, 2SLS, Cochrane-Orcutt procedure	West Germany	1960–1970	–	–0.55 to –0.97
Brissimis et al. (2002)	2SLS	Germany	1980–1992	–0.74	–0.22
	3SLS	Germany		–0.96	–0.40
Ouyang et al. (2007)	Simultaneous equations system estimated using 2SLS	China	1999–2005	–0.92 to –0.97	–0.63 to –0.70
Kim (1995)	OLS, 2SLS, GLS	Korea	1980–1994	–0.6 to –0.7	some –0.4
Pérez Campanero (1990)	OLS, 2SLS	Spain	1975–1989	–0.96; –0.90	–0.12; –0.16
Christensen (2004)	VAR	Czech Republic	1993–1996	–0.11	–0.15
Tomšík (1998)	2SLS	Czech Republic	1993–1996	–	0.57 – 0.83
Siklos (2001)	OLS	Hungary	1992–1997	–1.002	–
Palić (2005)	2SLS	Serbia	2001–2005	–0.81	–0.61
Emir et al. (2000)	Simultaneous equations system estimated using 2SLS	Turkey	1990–1993	–0.54	–0.29
			1995–1999	–0.88	–0.78
Celasun et al. (1999)	2SLS	Turkey	1989–1997	–0.37	–
Altinkemer (1998)	OLS	Turkey	1990–1997	–0.82; –0.91	–
Waheed (2007)	VAR	Pakistan	2001–2006	–0.5	–0.16
Qayyum and Khan (2003)	Cointegration (Johansen)	Pakistan	1982–2001	–0.72	–
Jan et al. (2005)	OLS	Pakistan	2000–2003	–0.70 to –0.88	–
Hanke (2002)	OLS	Argentina	1991–2001	–0.59	–
		Bosnia and Herzegovina	1997–2002	–0.06	–
		Bulgaria	1998–2002	–0.76	–
		Estonia	1992–2002	–0.44	–
		Hong Kong	1994–2002	–0.73	–
		Lithuania	1994–2002	–0.73	–
Cavoli and Rajan (2005)	VAR, OLS	Korea	1990–1997	–1.11	–
		Indonesia		–0.76	–
		Thailand		–0.91	–
		Malaysia		–0.94	–
				–0.97	–

Appendix IV Results of the Hausman Test

The Hausman test for testing the endogeneity of variables is carried out so as to firstly estimate the reduced equation, which means that the tested variable is estimated by all other exogenous and instrumental variables. The residuals obtained from the estimation of the reduced equation are then included in the basic equation, which is then estimated using the ordinary least square method. The equation estimates calculated in this way are shown in Tables A and B.

Table A Results of the Hausman Endogeneity Test of the NFA Variable in the Monetary Policy Reaction Equation

Dependent variable: ΔNDA		
Method: Ordinary Least Squared		
Sample: February 2000 – April 2009		
No. of observations: 111		
Variable	**Coefficient**	**T-statistics**
Const.	0.0102[a]	2.7498
Δ*NFA*	–0.8089[a]	–2.8418
Δlog *MM*4	–0.4011[a]	–6.2621
Δlog *IND_PR*	0.1746[b]	2.0858
Δ*TZ_*182	–0.0117[b]	–2.2285
HAUSMAN_RESID	0.1262	0.4291
R^2	0.5667	
Adjusted R^2	0.5460	

[a] and [b] indicate the significance level of 1% and 5%.
Source: Authors' calculations.

Table B Results of the Hausman Endogeneity Test of the NDA Variable in the Capital-Flow Equation

Dependent variable: ΔNFA		
Method: Ordinary Least Squared		
Sample: February 2000 – April 2009		
No. of observations: 111		
Variable	**Coefficient**	**T-statistics**
Const.	0,0093[a]	3,7419
Δ*NDA*	–0,4801[a]	–3,0503
Δlog *MM*4	–0,2833[a]	–5,1231
Δlog *HRK_EUR*	–0,9316[a]	–3,0738
Δlog *PUB_DEB*	0,3202[b]	2,3788
HAUSMAN_RESID	–0,1539	–0,8715
R^2	0,5280	
Adjusted R^2	0,5055	

[a] and [b] indicate the significance level of 1% and 5%.
Source: Authors' calculations.

Since the coefficients for the residuals are statistically insignificant in both cases, according to the Hausman test it may be concluded that the hypothesis on the consistency of the OLS estimation can not be rejected for either of the equations under review. Irrespective of this, for theoretical reasons this paper is based on the results of the 2SLS estimation.

Appendix V Results of Equations Estimated Using Ordinary Least Squares (OLS) Method

Table C Results of the Monetary Policy Reaction Equation Estimated Using Ordinary Least Squares Method

Dependent variable: ΔNDA		
Method: Ordinary Least Squared		
Sample: February 2000 – April 2009		
No. of observations: 111		
Variable	**Coefficient**	**T-statistics**
Const.	0.0090[a]	4.0199
Δ*NFA*	–0.6907[a]	–9.6590
Δlog *MM4*	–0.3780[a]	–9.3369
Δlog *IND_PR*	0.1754[b]	2.1051
Δ*TZ_182*	–0.0104[b]	–2.4724
R^2	0.5659	
Adjusted R^2	0.5495	
F-statistics	34.5471	
Probability (F-statistics)	0.0000	

[a] and [b] indicate the significance level of 1% and 5%.
Source: Authors' calculations.

Table D Results of the Capital-Flow Equation Estimated Using Ordinary Least Squares Method

Dependent variable: ΔNFA		
Method: Ordinary Least Squared		
Sample: February 2000 – April 2009		
No. of observations: 111		
Variable	**Coefficient**	**T-statistics**
Const.	0.0098[a]	3.6642
Δ*NDA*	–0.6023[a]	–4.8104
Δlog *MM4*	–0.3120[a]	–7.7120
Δlog *PUB_DEB*	0.2946[a]	2.7489
Δlog *HRK_EUR*	–0.8359[a]	–3.3054
R^2	0.5245	
Adjusted R^2	0.5066	
F-statistics	29.2365	
Probability (F-statistics)	0.0000	

[a] and [b] indicate the significance level of 1% and 5%.
Source: Authors' calculations.

References

Alberola, E., and J. M. Serena (2007): *Global Financial Integration, Monetary Policy and Reserve Accumulation. Assessing the Limits in Emerging Economies*, Banco de Espana, paper No. 0706.

Brissimis, S., H. Gibson, and E. Tsakalotos (2002): *A Unifying Framework for Analyzing Offsetting Capital Flows and Sterilization: Germany and the ERM*, International Journal of Finance and Economics 7, pp. 63-78.

Altinkemer, M. (1998): *Capital Inflows and Central Bank's Policy Response*, The Central Bank of the Republic of Turkey, December 1998.

Calvo, G. A. (1990): *The Perils of Sterilization*, IMF, paper No. wp/90/13.

Cavoli, T. (2005): *Sterilisation, Capital Mobility and Interest Rate Determination for East Asia,* School of Economics University of Adelaide, paper No. 2005-5.

Cavoli, T., and R. S. Rajan (2005): *The Capital Inflows Problem in Selected Asian Economies in the 1990s Revisited: The Role of Monetary Sterilization*, Singapore Centre for Applied and Policy Economics, paper No. 2005/18.

Celasun, O., C. Denizer, and D. He (1999): *Capital Flows, Macroeconomic Management and Financial System – Turkey 1989-97*, World Bank.

Christensen, J. (2004): *Capital Inflows, Sterilization, and Commercial Bank Speculation: The Case of the Czech Republic in the Mid-1990s*, IMF, paper No. wp/04/218.

Clavijo, S., and C. Varela (2003): *Floating Exchange Rate and Monetary Sterilization: The Experience of Colombia*, Banco de la Republica de Colombia.

Cumby, R. E., and M. Obstfeld (1981): *Capital Mobility and the Scope for Sterilization: Mexico in the 1970s*, NBER, paper No. 770.

Disyatat, P., and G. Galati (2005): *The Effectiveness of Foreign Exchange Intervention in Emerging Market Countries*, BIS, paper No. 24, pp. 97-113.

Emir, O. Y., A. Karasoy, and K. Kunter (2000): *Monetary Policy Reaction Function in Turkey*, Central Bank of the Republic of Turkey, October 2000.

Hanke, S. H. (2002): *On Dollarization and Currency Boards: Error and Deception, Journal of Economic Policy Reform*, 5:4, pp. 203-222.

Croatian National Bank (2006): *Analiza inozemne zaduženosti Republike Hrvatske*, http://www.hnb.hr/publikac/ostale-publikacije/h-analiza-inozemne-zaduzenosti-rh.pdf

Jan A., A. Elahi, and M. A. Zahid (2005): *Managing Foreign Exchange Inflows: An Analysis of Sterilisation in Pakistan*, The Pakistan Development Review 44:4, pp. 777-792.

Kim, G. (1995): *Exchange Rate Constraints and Money Control in Korea,* Federal Reserve Bank of St. Louis, paper No. 1995-011A.

Kouri, P., and R. Porter (1974): *International Capital Flows and Portfolio Equilibrium*, Journal of Political Economy, Vol. 82, pp. 443-467.

Kraft, E., and Lj. Jankov (2005): *Does Speed Kill? Lending Booms and Their Consequences in Croatia*, Journal of Banking and Finance, Vol. 29, No. 1, pp. 105-121.

Leiderman, L. (1984): *On the Monetary-Macro Dynamics of Colombia and Mexico*, Journal of Development Economics, Vol. 14, pp. 183-201.

Mastropasqua, C., S. Micossi, and R. Rinaldi (1988): *Interventions, Sterilization and Monetary Policy in European Monetary System Countries, 1979-87*, in: F. Giavazzi, S. Micossi and M. Miller, *The European Monetary System*, Cambridge University Press, Cambridge.

Mihaljek, D. (2005): *Survey of Central Banks' Views on Effects of Intervention*, BIS, paper No. 24, pp. 82-96.

Moreno, R. (1996): *Intervention, Sterilization, and Monetary Control in Korea and Taiwan*, FRBSF Economic Review, 1996, No. 3.

Obstfeld, M. (1980): *Can We Sterilize? Theory and Evidence,* NBER, paper No. 833

Obstfeld, M. (1982): *Sterilization and the Offsetting Capital Movements, Evidence from West Germany, 1960-1970*, NBER, paper No. 494.

Obstfeld, M. (1983): *Exchange Rate, Inflation and the Sterilization Problem: Germany, 1975-1981*, NBER, paper No. 963.

Otker-Robe, I., Z. Polański, B. Topf, and D. Vávra (2007): *Coping with Capital Inflows: Experiences of Selected European* Countries, IMF, paper No. wp/07/190.

Ouyang, A. Y., and R. S. Rajan (2005): *Monetary Sterilization in China Since the 1990s: How Much and How Effective?*, Centre for International Economic Studies, Adelaide University, paper No. 0507.

Ouyang, Y. A., R. S. Rajan, and T. D. Willett (2007): *China as a Reserve Sink: The Evidence from Offset and Sterilization Coefficients*, Hong Kong Institute for Monetary Research, paper No. 10/2007.

Qayyum, A., and A. Khan (2003): *Capital Flows and Money Supply: The Degree of Sterilisation in Pakistan,* The Pakistan Development Review 42:4, pp. 975-985.

Palić, M. (2005): *povlačenja primarnog novca – rezultati empirijske analize,* Working paper of the National Bank of Serbia,

http://www.nbs.yu/export/internet/latinica/90/90_0/sterilizacija_MP_122005.pdf

Patniak, I. (2005): *India's Experience with a Pegged Exchange Rate*, in: Suman Bery, Barry Bosworth, and Arvind Panagariya, editors, *The India Policy Forum 2004*, Brookings Institution Press and NCAER, pp. 189-226.

Pérez Campanero, J. P. (1990) *El problema de la esterilización: interacciones entre política monetaria e intervención en los mercados de divisas***,** Moneda y Crédito 191, pp. 97-132.

Rohatinski, Ž. (2004): *Monetarna politika*, Ekonomski pregled, 55 (11-12), pp. 1018-1023.

Roubini, N. (1988): *Offset and Sterilization Under Fixed Exchange Rate,* NBER, paper No. 2777

Sarno, L., and M. P. Taylor (2001): *Official Intervention in the Foreign Exchange Market; Is It Effective, and If So, How Does It Work?*, Journal of Economic Literature, Vol. 34, pp. 839 -868.

Siklos, P. L. (2001): *Capital Flows in a Transitional Economy and the Sterilization Dilemma: The Hungarian Experience, 1992-97*, Policy Reform, Vol. 3, pp. 373-392.

Tomšík, V. (1998): *Vyzkum kompenzacniho koeficientu v podminkach CR v letech 1993-1996*, Finance a úvěr, No. 6, pp. 357-379.

Waheed, M. (2007): *Central Bank Intervention, Sterilization and Monetary Independence: The Case of Pakistan*, MPRA paper No. 2328.

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