Optimal Foreign Reserves
The Case of Croatia

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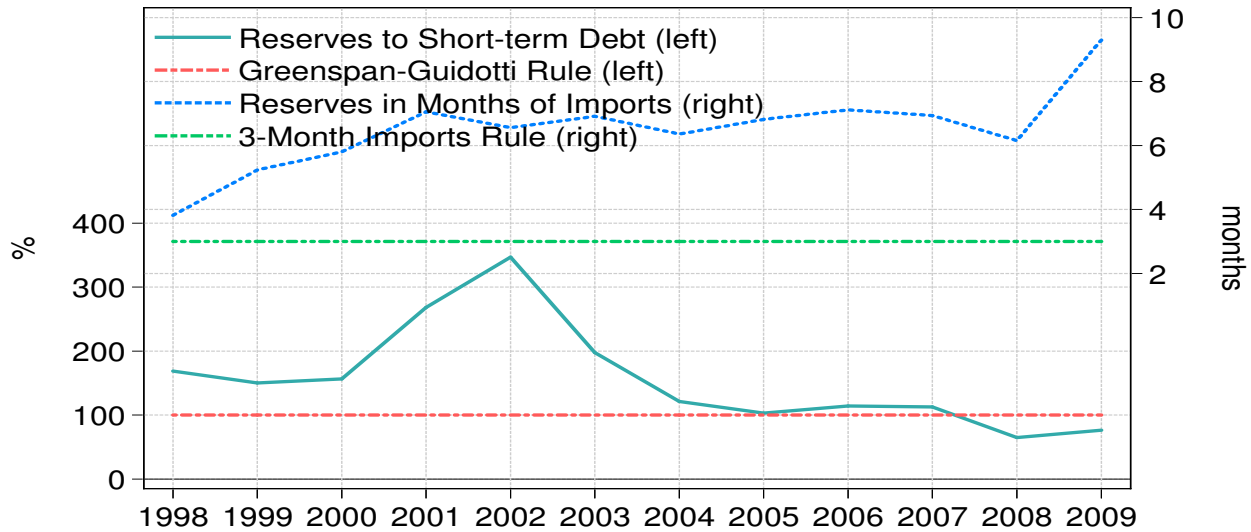
Motivation

- the optimal level of foreign reserves a central bank (CNB) should hold?
- are CNB foreign reserves sufficient to mitigate negative effects of potential sudden-stop of capital inflows which comes along with banking crisis?
- can we find rationale for huge CNB reserves accumulation during the last 10 years (quadrupled since 1998)
- alternative measure of foreign reserves adequacy in dollarized economy
- comparison of "optimal reserves" to standard indicators of foreign reserves adequacy

Why alternative measure?

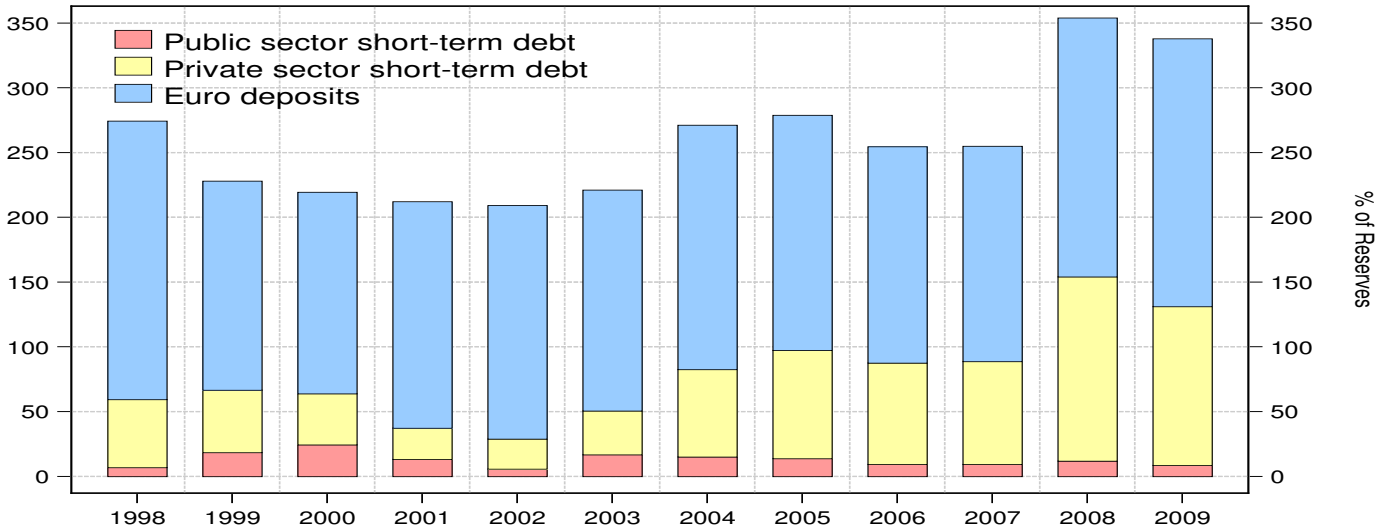
- standard indicators of foreign reserves adequacy (Greenspan-Guidotti 100%-of-short-term debt rule and 3-months-of-imports rule)
  - based on arbitrary thresholds
  - taking into account only benefits (but not costs) of holding reserves



- BENEFITS: insurance against sudden stop/banking crisis episodes
- COSTS: opportunity costs of holding reserves - repaying external debt, investing in (riskier) assets yielding higher returns

Why alternative measure?

- standard indicators emphasize precautionary motives for holding reserves but are not taking into account potential vulnerabilities of the economy
- sources of vulnerabilities



- in dollarized economies protection role of reserves is more important: insurance against sudden stop and key tool for managing domestic financial (in)stability by lessening credit crunch during bank run

The Plan

- provide a new measure based on optimality criterion and capturing all the vulnerabilities an economy (Croatian economy) is exposed to
- building a model (based on stylized facts) of precautionary demand for reserves in a dollarized economy that is subject to sudden stop which occurs in hand with banking crisis
- "simulate" the model and compare optimal and CNB accumulated reserves throughout the history (to see if the precautionary demand for reserves can explain huge increase of reserves during the last 10 years)
- see if today the CNB is holding enough reserves to fight possible crisis
- comparing a new measure of reserves adequacy with the standard ones

Stylized facts and the Model

- simple (two period) model with 3 sectors (non-financial: households/firms, financial: banks, government/central bank) similar to Jeanne, Ranciere (2008)
- first period: tranquil period (before crisis)
- second period: crisis period
  - short-term debt of every sector is not rolled over
  - GDP falls
  - exchange rate depreciates (goes up)
  - part of domestic currency (kuna) deposits is exchanged into foreign currency (euro) deposits
  - bank run on kuna and euro deposits
  - banks and firms withdraw their liquid foreign assets to use them as a buffer against a crisis

Non-financial sector before crisis

- maximize (expected: the only source of uncertainty comes from probability of crisis) lifetime utility subject to budget constraint (get deterministic exogenous endowment y_t that is growing over time at the rate of g)

Assets	**Liabilities**
kuna deposits, $d_t^k (= d_t^{kh} + d_t^{kc})$	short-term kuna loans, l_t^k
euro deposits, $S_t\ d_t^f = S_t\ (d_t^{fh} + d_t^{fc})$	short-term euro loans, $S_t\ l_t^f$
foreign liquid assets, $S_t\ FRB_t^h$	short-term foreign borrowing, $S_t\ b_t$
profits, Π_t	
government transfers, T_t	

Non-financial sector during crisis

- kuna depreciates (by an absolute change of ΔS), access to foreign loans market is canceled
- a fraction, η of kuna deposits is exchanged into euro deposits and a fraction of overall deposits, ϕ is withdrawn from banks: kuna household deposits together with kuna and euro corporate deposits and foreign liquid assets will act as a buffer against sudden stop effects

Assets	Liabilities
kuna household deposits, $d_t^{kh} - \phi(1-\eta)d_t^{kh}$	short-term kuna loans, l_t^k
euro household deposits, $(S_t + \Delta S)d_t^{fh}$	short-term euro loans, $(S_t + \Delta S)\, l_t^f$
kuna corporate deposits, $d_t^{kc} - \phi(1-\eta)d_t^{kc}$	short-term foreign borrowing, $(S_t + \Delta S)\, b_t = 0$
euro corporate deposits, $(S_t + \Delta S)d_t^{fc} - (S_t + \Delta S)\phi(d_t^{fc} + \frac{\eta}{S+\Delta S}\, d_t^{kc})$	
foreign liquid assets, $S_t\, FRB_t^h = 0$	
profits, Π_t	
government transfers, T_t	

Optimization problem - nonfinancial sector

- houselds maximize the expected discounted value of utility to make optimal decisions on how much to consume, how much to save and how much to borrow

$$\max_{\left\{c_t, I_t^f, I_t^k, b_t, d_t^{fh}, d_t^{fc}, d_t^{kh}, d_t^{kc}, FRB_t^h\right\}_{t=0}^{\infty}} E_0 \left\{ \sum_{t=0}^{\infty} \beta^t u(c_t) \right\}$$

subject to budget constraints
before crisis:

$$P_t c_t + S_t(1+r) I_{t-1}^f + (1+r) I_{t-1}^k + S_t(1+r) b_{t-1} + S_t(d_t^{fh} + d_t^{fc}) + (d_t^{kh} + d_t^{kc}) +$$

$$S_t\, FRB_t^h = P_t y_t + S_t\, I_t^f + I_t^k + S_t\, b_t + S_t(1+r)(d_{t-1}^{fh} + d_{t-1}^{fc}) + (1+r)(d_{t-1}^{kh} + d_{t-1}^{kc}) +$$

$$+ S_t(1+r) FRB_{t-1}^h + \Pi_t + T_t$$

during crisis:

$$P_t c_t + (S_t + \Delta S)(1+r) I_{t-1}^f + (1+r) I_{t-1}^k + (S_t + \Delta S)(1+r) b_{t-1} +$$

$$+ (S_t + \Delta S)(d_t^{fh} + d_t^{fc}) + (d_t^{kh} + d_t^{kc}) =$$

$$(1-\gamma) P_t y_t + (S_t + \Delta S) I_t^f + I_t^k + (S_t + \Delta S)(1+r)(d_{t-1}^{fh} + d_{t-1}^{fc}) +$$

$$+ (1+r)(d_{t-1}^{kh} + d_{t-1}^{kc}) + (S_t + \Delta S)\phi(d_t^{fc} + \frac{\eta}{S_t + \Delta S} d_t^{kc}) + \phi(1-\eta)(d_t^{kh} + d_t^{kc})$$

$$+ (S_t + \Delta S)(1+r) FRB_{t-1}^h + \Pi_t + T_t$$

Financial sector before crisis

- banks maximize profits (returned to households - owners of banks)

Assets	Liabilities
short-term kuna loans, l_t^k	kuna deposits, $d_t^k (= d_t^{kh} + d_t^{kc})$
short-term euro loans, $S_t\, l_t^f$	euro deposits, $S_t\, d_t^f = S_t\, (d_t^{fh} + d_t^{fc})$
reserve requirement, $RB_t^k + S_t\, RB_t^f$	short-term foreign borrowing, $S_t\, FB_t$
foreign liquid assets, $S_t\, FRB_t^b$	

Financial sector during crisis

- issuing new foreign debt is no longer possible
- loss of confidence in kuna + bank run on overall deposits
- using foreign liquid assets to fight sudden-stop and bank run

Assets	**Liabilities**
short-term kuna credits, l_t^k	kuna household deposits, $d_t^{kh} - \phi(1-\eta)d_t^{kh}$
short-term euro loans, $(S_t + \Delta S)\, l_t^f$	euro household deposits, $(S_t + \Delta S)d_t^{fh} - (S_t + \Delta S)\phi(d_t^{fh} + \frac{\eta}{S_t+\Delta S}\, d_t^{kh})$
reserve requirement, $RB_t^k + (S_t + \Delta S)\, RB_t^f$	kuna corporate deposits, $d_t^{kc} - \phi(1-\eta)d_t^{kc}$
foreign liquid assets,$(S_t + \Delta S)\, FRB_t^b = 0$	euro corporate deposits, $(S_t + \Delta S)d_t^{fc} - (S_t + \Delta S)\phi(d_t^{fc} + \frac{\eta}{S_t+\Delta S}\, d_t^{kc})$
	short-term foreign borrowing, $(S_t + \Delta S)\, FB_t = 0$

Optimization problem - financial sector

- bank is choosing domestic deposit demand, domestic loan supply and international net borrowing so as to maximize its profit (returned to households) taking interest rates and exchange rate as given

$$\max_{\{d_t^{fh}, d_t^{fc}, d_t^{kh}, d_t^{kc}, l_t^f, l_t^k, FB_t, RB_t^k, RB_t^f, FRB_t^b\}_{t=0}^{\infty}} E_0 \left\{ \sum_{t=0}^{\infty} Q_{t,0}\, \Pi_t \right\}$$

subject to:
profits before crisis:

$$\begin{aligned}
\Pi_t &= S_t(d_t^{fh} + d_t^{fc}) + (d_t^{kh} + d_t^{kc}) + S_t(1+r)l_{t-1}^f + (1+r)l_{t-1}^k + \\
&+ S_t\, FB_t + RB_{t-1}^k + S_t\, RB_{t-1}^f + S_t(1+r)FRB_{t-1}^b - \\
&- S_t(1+r)(d_{t-1}^{fh} + d_{t-1}^{fc}) - (1+r)(d_{t-1}^{kh} + d_{t-1}^{kc}) - S_t\, l_t^f - l_t^k - \\
&- S_t(1+r)FB_{t-1} - RB_t^k - S_t\, RB_t^f - S_t\, FRB_t^b
\end{aligned}$$

profits during crisis:

$$\begin{aligned}
\Pi_t &= (S_t + \Delta S)(d_t^{fh} + d_t^{fc}) + (d_t^{kh} + d_t^{kc}) + (S_t + \Delta S)(1+r)l_{t-1}^f + (1+r)l_{t-1}^k + \\
&+ RB_{t-1}^k + (S_t + \Delta S)RB_{t-1}^f + (S_t + \Delta S)(1+r)FRB_{t-1}^b - \\
&- (S_t + \Delta S)(1+r)(d_{t-1}^{fh} + d_{t-1}^{fc}) - (S_t + \Delta S)\phi[(d_t^{fh} + d_t^{fc}) + \frac{\eta}{S_t + \Delta S}(d_t^{kh} + d_t^{kc})] - \\
&- (1+r)(d_{t-1}^{kh} + d_{t-1}^{kc}) - \phi(1-\eta)(d_t^{kh} + d_t^{kc}) - (S_t + \Delta S)\, l_t^f - l_t^k - \\
&- (S_t + \Delta S)(1+r)FB_{t-1} - RB_t^k - (S_t + \Delta S)RB_t^f
\end{aligned}$$

Government before crisis

- issuing long-term security (at a term premium) to finance a stock of international reserves and running a balanced budget

Assets	Liabilities
international reserves, $S_t\ R_t$	short-term foreign borrowing, $S_t\ FG_t$ long-term foreign borrowing, $S_t\ PN_t\ -\ S_t\ PN_{t-1}$ reserve requirement, $RB_t^k + S_t\ RB_t^f$ government transfers, T_t

Government during crisis

- issuing new short-term foreign debt is no longer possible

Assets	Liabilities
international reserves, $(S_t + \Delta S)R_t$	short-term foreign borrowing, $(S_t + \Delta S)FG_t = 0$ long-term foreign borrowing, $(S_t + \Delta S)PN_t$ reserve requirement, $RB_t^k + (S_t + \Delta S)RB_t^f$ government transfers, T_t

Government

- choosing international reserves to maximize the welfare of the economy

$$\max_{c_t, R_t} \beta E_t[u(c_{t+1})] = \max_{c_t, R_t} \beta \left[(1-\pi)\, u(c^b_{t+1}) + \pi u(c^d_{t+1})\right]$$

subject to consolidated budget constraint:
before crisis

$$P_t c^b_t + S_t(1+r)b_{t-1} + S_t\, FRB^h_t = P_t y_t + S_t\, b_t + S_t(1+r)FRB^h_{t-1} + S_t\, FB_t +$$
$$+S_t(1+r)FRB^b_{t-1} - S_t(1+r)FB_{t-1} - S_t FRB^b_t - S_t(1+r)FG_{t-1} + S_t\, FG_t -$$
$$-S_t\ (\delta+\pi)R_{t-1}$$

during crisis

$$P_t c^d_t + (S_t+\Delta S)(1+r)b_{t-1} = (1-\gamma)P_t y_t + (S_t+\Delta S)(1+r)FRB^h_{t-1} +$$
$$+(S_t+\Delta S)(1+r)FRB^b_{t-1} - (S_t+\Delta S)\phi(d^{fh}_t + \frac{\eta}{S_t+\Delta S} d^{kh}_t) -$$
$$-(S_t+\Delta S)(1+r)FB_{t-1} - (S_t+\Delta S)(1+r)FG_{t-1} +$$
$$+(S_t+\Delta S)(1-\delta-\pi)R_{t-1}$$

Optimality condition

- first order condition with respect to R_t:

$$S_{t+1}(1-\pi)(\delta+\pi)u'(c^b_{t+1}) = (S_{t+1}+\Delta S)\pi(1-\delta-\pi)u'(c^d_{t+1})$$

- balances costs and benefits of holding reserves - expected marginal cost of holding reserves before sudden-stop (left hand side) equals expected marginal benefit of holding reserves during the crisis (right hand side)

Level of optimal foreign reserves

- level of optimal foreign reserves

$$R_t = \frac{1}{q_{t+1}}\left\{(1-\varepsilon^{\gamma}_{t+1})(1+g)\frac{y_t P_{t+1}}{S_{t+1}} + [\lambda^{*}_{t+1} - (1+r)(1-\varepsilon^{s}_{t+1})\lambda^{*}_{t}] - \right.$$
$$\left. - \left[\lambda^{A}_{t+1} - (1+r)(1-\varepsilon^{s}_{t+1})\lambda^{A}_{t}\right] + \phi\varepsilon^{s}_{t+1}\lambda^{D}_{t+1}\right\}$$

where $\varepsilon^{\gamma}_{t+1}, \varepsilon^{s}_{t+1}, q_{t+1}$ are functions of $(\pi, \delta, \Delta S, \gamma)$ and

$$\lambda^{*}_{t} = b_t + FB_t + FG_t,\ \lambda^{A}_{t} = FRB^{h}_{t} + FRB^{b}_{t},\ \lambda^{D}_{t} = d^{fh}_{t} + \frac{\eta}{S_t + \Delta S} d^{kh}_{t}$$

- optimal reserves increase with probability of crisis, depreciation of kuna and output loss; decrease with term premium
- comparing with Greenspan-Guidotti: $R_t = \lambda^{*}_{t+1}$

Calibration of the model and data

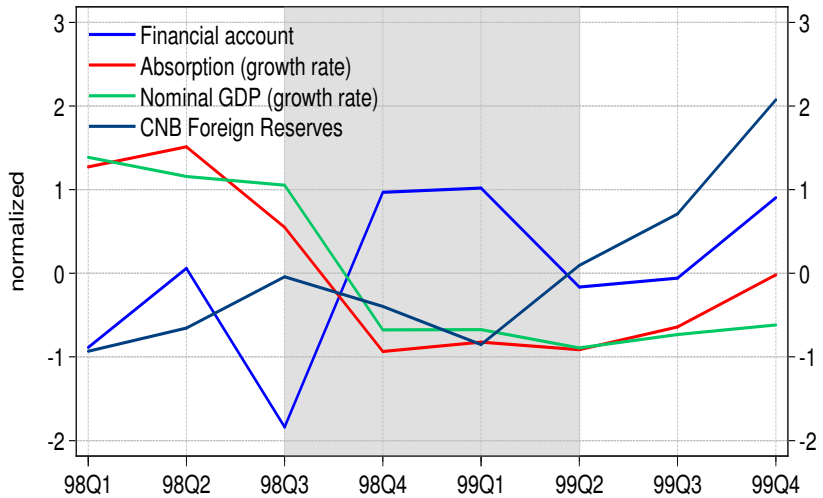
- calibrating model's parameters to match the 1998/1999 sudden-stop/banking crisis
- short-term external debt data includes principal payments of its long term debt that are due
- differentiation between two models of parent banks' behavior (two definitions of short-term debt)
  - *Lenders of Last Resort* - mother banks do not participate in sudden-stop
    - they convert their short-term funding into long-term funding
    - short-term debt of mother banks is excluded from the short-term external debt data
  - *Take the Money and Run* - mother banks participate in sudden-stop

Sudden-stop 1998/1999

- Croatia - highly dollarized (euroized) economy
- crisis 1998 – 1999 - double drain risk
  - external drain risk
    - sudden-stop of foreign capital inflows
    - foreign creditors stopped providing credits to Croatian economy
    - financial account reversal
  - internal drain risk
    - banking crisis
    - lost confidence in banking system
    - deposit run
    - credit crunch

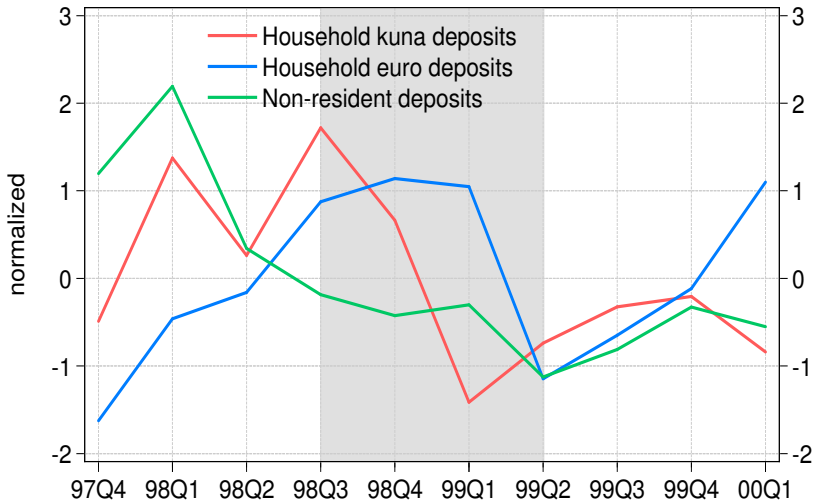
Sudden-stop 1998/1999

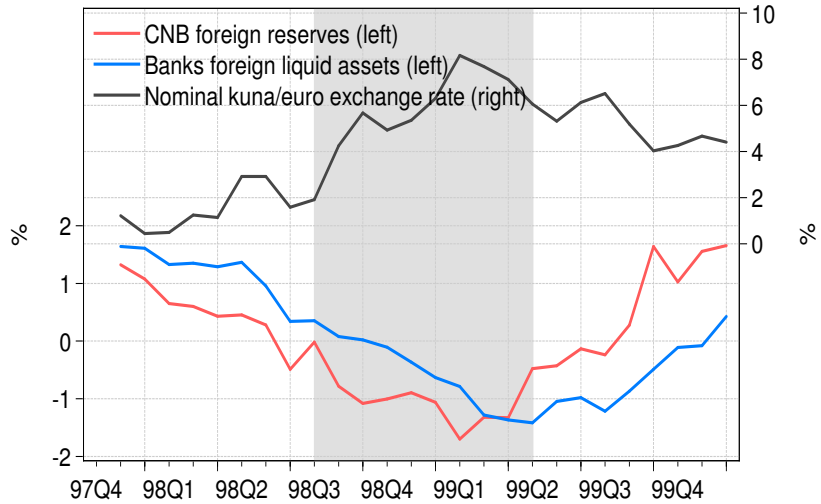
- short-term debt is not rolled over
- growth rate of GDP falls



Sudden-stop 1998/1999

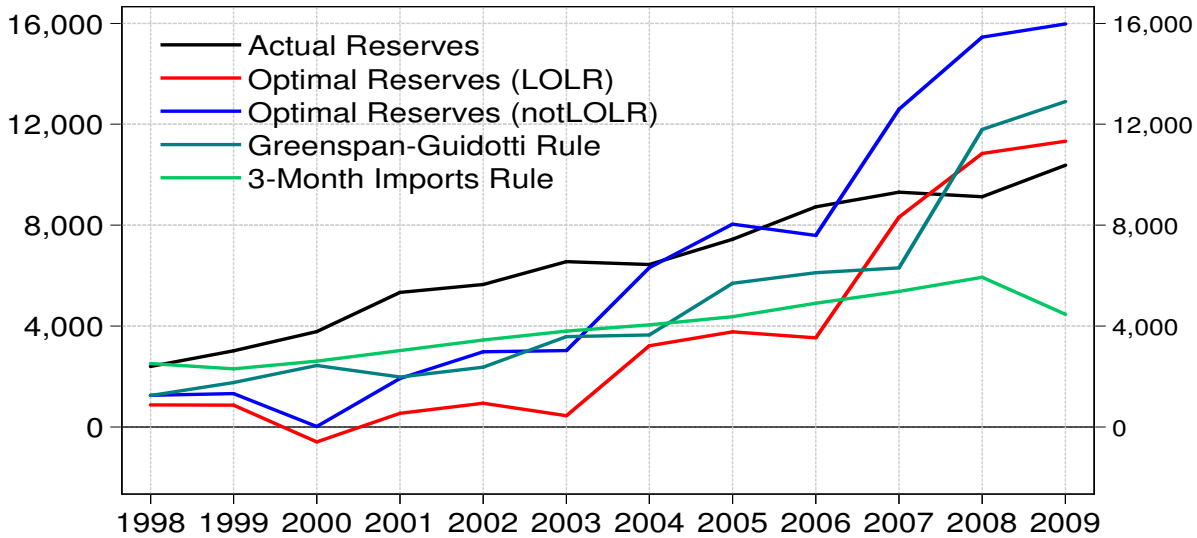
- sudden-stop is triggering first a loss of confidence in domestic currency and then a bank run (left figure)
- banks are liquidating their buffer foreign reserves to mitigate bank run (right figure)
- exchange rate kuna/euro depreciates (right figure)





Optimal and actual foreign reserves

- optimal foreign reserves - depend on assumed mother banks' behavior
- standard indicators of reserve adequacy do not take into account alternative sources of funding nor the parameters reflecting common features of sudden-stops with banking crisis (output loss, bank run)



Optimization problem

- government chooses the level of consumption in order to maximize expected discounted welfare of the economy

$$\max_{c_t, R_t} \beta E_t(c_{t+1}) = \max_{c_t, R_t} \beta \left[(1-\pi)\, u(c^b_{t+1}) + \pi u(c^d_{t+1}) \right]$$

subject to consolidated budget constraint:
before crisis

$$P_t c^b_t + S_t(1+r)b_{t-1} + S_t\, FRB^h_t = P_t y_t + S_t\, b_t + S_t(1+r)FRB^h_{t-1} + S_t\, FB_t +$$
$$+S_t(1+r)FRB^b_{t-1} - S_t(1+r)FB_{t-1} - S_t FRB^b_t - S_t(1+r)FG_{t-1} + S_t\, FG_t -$$
$$-S_t\, (\delta+\pi)R_{t-1}$$

during crisis

$$P_t c^d_t + (S_t + \Delta S)(1+r)b_{t-1} = (1-\gamma)P_t y_t + (S_t+\Delta S)(1+r)FRB^h_{t-1} +$$
$$+(S_t+\Delta S)(1+r)FRB^b_{t-1} - (S_t+\Delta S)\phi(d^{fh}_t + \frac{\eta}{S_t+\Delta S} d^{kh}_t) -$$
$$-(S_t+\Delta S)(1+r)FB_{t-1} - (S_t+\Delta S)(1+r)FG_{t-1} +$$
$$+(S_t+\Delta S)(1-\delta-\pi)R_{t-1}$$

Endogenous probability

- probability of crisis is endogenous $\pi_t = \pi(R_t), \pi' < 0$
  - government chooses reserves level which maximizes previous problem
  - optimal reserves level depends on the probability of the crisis
  - choosing certain level of reserves the government influences the probability of a crisis
- no analytical solution
- endogenous probability model is solved numerically

$$V(R_t) = \max_{R_t} \left[(1 - \pi(R_t)) u^{bs}(R_t) + \pi(R_t) u^{ds}(R_t) \right]$$

subject to (consolidated) budget constraint where
welfare of the economy if no crisis occurs

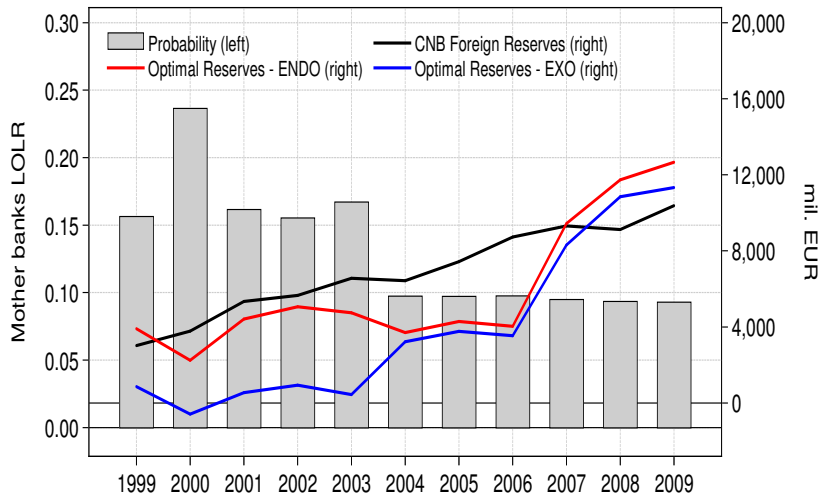
$$u^{bs}(R_t) = u\left(c_t^b\right) + \beta V(R_t^*)$$

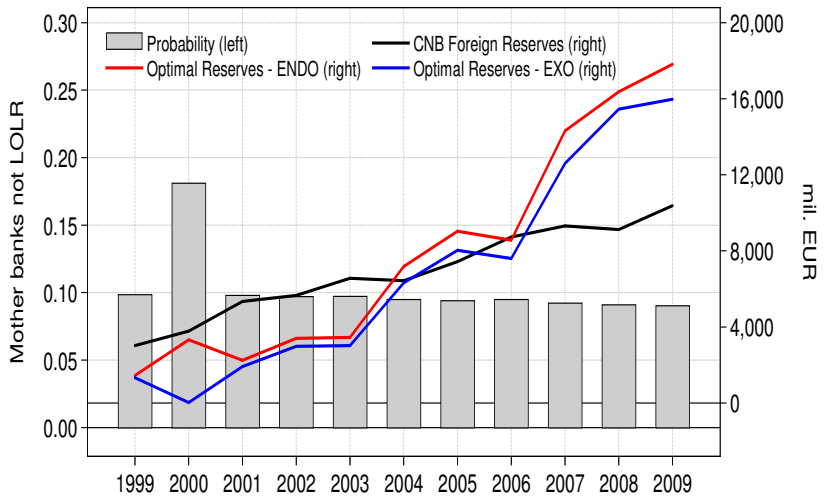
welfare of the economy if crisis occurs

$$u^{ds}(R_t) = u\left(c_t^d\right) + \beta u^{bs}(R_t^*)$$

Optimal and actual foreign reserves

- probability of crisis - exogenous/endogenous
- differentiation between mother banks' behavior
  - Lenders of Last Resort (left figure)
  - Take the Money and Run (right figure)





Conclusion

- precautionary motives behind reserves accumulation since 2004.
- optimality of foreign reserves depends on assumed behavior of mother banks during crisis
- standard indicators of reserve adequacy do not take into account many features of sudden-stop/banking crisis episode - might be misleading
- CNB's foreign reserves are (nearly) sufficient to fight the crisis of 1998/1999 magnitude if mother banks act as lenders of last resort