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SHORT-TERM CURRENCY IN CIRCULATION FORECASTING FOR MONETARY POLICY PURPOSES – THE CASE OF POLAND

Witold Koziński[1] Tomasz Świst[2]

Abstract

One of the most significant factors which influences the level of banking sector liquidity is Currency in Circulation. Although the central bank is in charge of distribution of the currency it can't assess the demand for the currency, as that demand is generated by the customers of commercial banks. Therefore, the amount of Currency in Circulation has to be modelled and forecasted. This paper introduces ARIMA(2,1) and SARIMA(2,1)(5,0) models with dummy variables and discusses its applicability to the forecasting of Currency in Circulation. The forecasting performance of these models is compared. The results indicate that the performance of SARIMA(2,1)(5,0) is better and that both models might be applied for monetary policy purposes as supportive tools for banking sector liquidity forecasting.

JEL classification: C01, C53, E52
Keywords: Currency in Circulation, Banking Sector Liquidity, Monetary Policy

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[1] National Bank of Poland, Witold.Kozinski@nbp.pl.
[2] National Bank of Poland, Tomasz.Swist@nbp.pl.

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Introduction

The gradual increments of short-term banking sector liquidity in Poland since 2009 implied the need to strengthen the liquidity management framework by the National Bank of Poland and gave an apparent role to Open Market Operations (OMOs). In particular, it was necessary to update the existing daily liquidity forecast techniques so that they could provide accurate information on short-term liquidity needs, which could be managed with the use of regular (as well as fine-tuning) OMOs.

The main banking sector liquidity forecasting horizon (of the daily liquidity forecasts) is the reserve requirement maintenance period, which lasts from 4 to 5 weeks. However, within each reserve maintenance period, the main open market operations are held on a weekly basis (the NBP conducts them on Fridays), so the forecasting horizon of up to five working days is at a similar level of importance.

The daily banking sector liquidity forecast is determined by the accuracy of its individual components. While some items are under the central bank's control, others are influenced by external factors, which are under direct control of the central bank in the short-run. Those autonomous factors determine the change in demand and supply of commercial bank reserves that the central bank needs to balance by conducting open market operations. Especially important are currency in circulation (with vault cash) and government deposits (in domestic currency), whose movements increase or decrease the amount of commercial bank reserves and directly influence liquidity conditions. Whereas the government deposit is the most unpredictable item in liquidity forecasting, currency in circulation shows some periodic patterns. This facilitates forecasting the short-term movement of currency. Due to the importance of currency in circulation for conducting monetary policy, many central banks have developed and applied econometric models for forecasting purposes.

One of the first papers describing the importance of modelling Currency in Circulation was the publication by Cabrero A., Camba-Mendez G., Hirsch A., Nieto F. (2002), in which modelling the daily series of banknotes in circulation in the context of the liquidity management of the Eurosystem was presented. The authors applied two approaches, the ARIMA-based approach proposed by Bell W. and Hillmer S. (1983) and Structural Time Series approach introduced by Harvey A., Koopman S. and Riani M. (1997). The forecasting performance of the models were assessed in the context of their impact on the liquidity management of the Eurosystem. The presented results suggest that two approaches are powerful and that the ARIMA model has the best forecasting performance over horizons of 5 days and more, while STS is the best for horizons of 1 to 4 days. The authors concluded that the best forecasting performance could be achieved by combining the two approaches.

In the Czech Republic, Hlaváček M., Michael Koňák M. and Čada J. (2005) introduced a feedforward structured neural network model and discussed its applicability to the forecasting of Currency in Circulation. The forecasting performance of the neural network model was compared with an ARIMA model described by 71 parameters. The results indicated that the performance of the neural network model was on average more accurate than ARIMA, however comparison of predictive accuracy with the use of a Diebold-Mariano test didn't show a statistically significant difference.

Dheerasinghe R. (2006) modelled Currency in Circulation for Sri Lanka with the use of three methods. Three separate models were estimated with daily, weekly and monthly time series, assembling tools for forecasting trends, seasonal patterns and cycles in separate individual series. Trend and seasonal effects were identified by regressing on trend and seasonal dummies, while cyclical dynamics were captured by allowing for an ARMA effect in the regression disturbances. The author concluded that all three models fit the data well and give very small estimation errors, which were less than 1% in all models tested in the post sample period.

Lang M., Kunovac D., Basač S. and Štaudinger Ž. (2008) described two time series models for forecasting Currency in Circulation outside banks in Croatia, i.e. regression (REG) and ARIMA models. Both models generated good short-term forecasts, completing each other in the sense that the REG outperformed the ARIMA model on the interval of up to 5 days ahead and on the other hand, the ARIMA model outperformed the first one in longer horizons. The authors stated that due to differences in the approach of those two models, combination of forecasts would outperform them.

In Turkey, daily changes of Currency in Circulation has been modelled by Güler H. and Talasli A. (2010). The authors introduced the ARIMA-GARCH(1,1) based approach to model seasonality in daily time series and evaluated forecasting performance. The results show that the forecasting performance of the model is better than the expert judgement both in the long and short run. Moreover the authors emphasized that the model has to be continuously revised to improve the quality of the forecasts and adjusted whenever needed.

Properties of currency in circulation time series in Poland

The Currency in Circulation (CiC) is one of the major autonomous factors in NBP's balance sheet (liabilities side), which plays one of the major roles in the context of banking sector liquidity management, both in term of its level as well as volatility. Due to the fact that CiC is out of direct control of the central bank its level and volatility can't be strictly deterministic. This feature of CiC implies the necessity of model calibration, which will allow us to forecast future developments as accurately as possible. The accuracy of a forecast, for monetary policy purposes, is measured by absolute deviation of the average level in a given reserve maintenance period.

From the operational realization of monetary policy the analysis considers CiC as the volume of all banknotes and notes in domestic currency including vault cash held by commercial banks. When CiC is returned to the central bank its level in the banking sector is decreasing and the level of banking sector liquidity is increasing and vice versa. During the days of a year, increases and decreases of CiC are the consequences of seasonal factors, such as:

1) the day effect in the week (denoted further as: MON, TUE, WEN, THE, FRI),

2) the day effect in the month (denoted further as: D1, … , D31),

3) the week effect in the month (denoted further as: W1, … , W5; where the 5th week is incomplete),

4) the month effect in the year (denoted further as: JAN, … , DEC),

5) the calendar effect of Easter (EAS) and Christmas (CHR), in here considered as a period of 5 working days before and 5 working days after the given calendar effect and

6) "the long weekend at the beginning of May" (LWM), the 1st and 3rd of May are holidays in Poland (Labour Day and Constitution Day, respectively).

As the series of CiC shows significant seasonality, comprising daily, weekly, monthly, annual patterns and some calendar effects like religious holidays, modelling CiC time series becomes a complex issue. Table 1 presents descriptive statistics of CiC time series (including descriptive statistics on a daily basis).

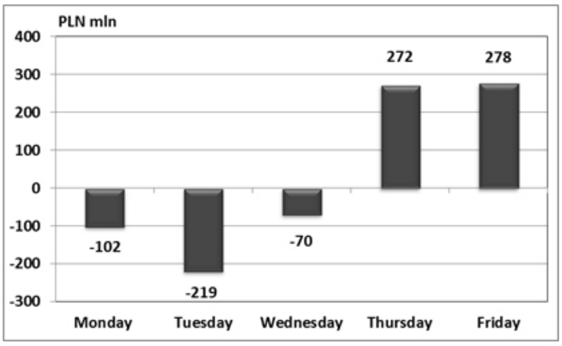
The trading day effect is one of the most significant and the shorter seasonal effects of CiC series. This effect is the consequence of changing demand for CiC during the week. Typically, the level of CiC decreases on Monday and this trend lasts till Wednesday. On Thursday and Friday usually systematic increases are observed, then there is an increased demand for CiC for the upcoming weekend. According to the CiC series, the level of CiC declines by 0,11% on Mondays, 0,24% on Tuesdays and 0,08% on Wednesdays and then increases by 0,30% and 0,32% on Thursdays and Fridays, on average (Figure 1 and Figure 2). Cumulative change in the level of CiC during the week is usually above zero.

Table 1: Descriptive Statistics of Cash in Circulation for Poland (in PLN mln)

	2006	2007	2008	2009	2010	2011
Level of CiC						
1st January	62 335	75 377	85 994	102 135	100 345	102 550
31st December	75 377	85 994	102 135	100 345	102 550	112 090
Change in the Year	13 042	10 617	16 141	-1 790	2 205	9 540
Average	68 227	79 719	91 267	100 602	101 097	106 293
Minimum	60 172	73 420	82 510	96 896	95 822	99 751
Maximum	76 381	87 873	104 457	104 134	106 407	114 703
Daily changes of CiC						
Average	49	41	62	-7	10	35
Minimum	-658	-873	-945	-1 018	-926	-1 054
Maximum	793	1 089	2 103	998	1 043	939
Standard deviation	303	331	414	365	363	368

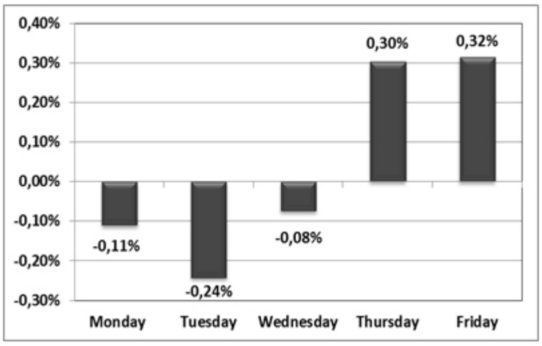
Source: National Bank of Poland

Figure 1: Trading Day Effect (in PLN mln)



Source: National Bank of Poland, averaged values, no-weekend holidays included

Figure 2: Trading Day Effect (in %)

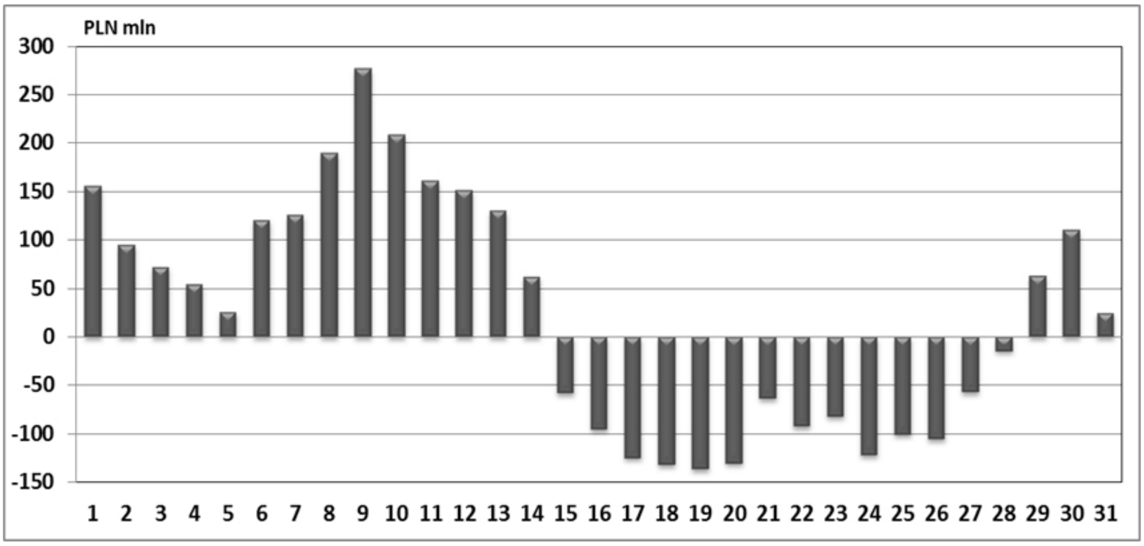


Source: National Bank of Poland, averaged values, no-weekend holidays included

Intra-monthly seasonal effect of CiC is associated with the payment of salaries, which are paid in Poland at the beginning of the month. On average, systematic increases in the level of CiC from the 1st to the 14th day of the month are observed. Then, from the 15th to the 28th, an opposite tendency takes place and after that, in the latter part of the month, CiC increases again (Figure 3).

The consequences of the observed cyclical changes in the following days of the month is the effect of the week in the month, where in the two first weeks of the month CiC increases and in the 3rd and 4th week usually declines. In the 5th week, which is *per se* incomplete, again increases are observed.

Figure 3: Intra-monthly Effect (in PLN mln)

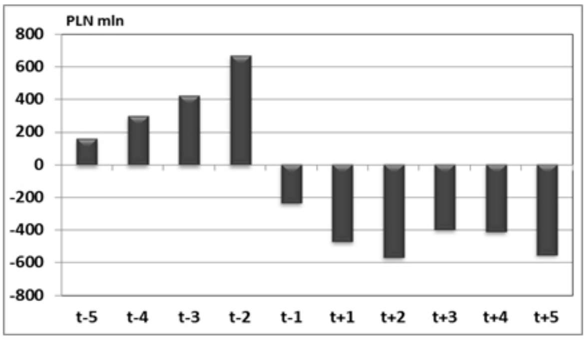


Source: National Bank of Poland, averaged values, included no-weekend holidays

In the broader context, modelling of CiC should be focused on the month in the year effect. Particularly noteworthy here is December, in which significant increase in demand for CiC is observed before the Christmas period, as shown in Figure 4.

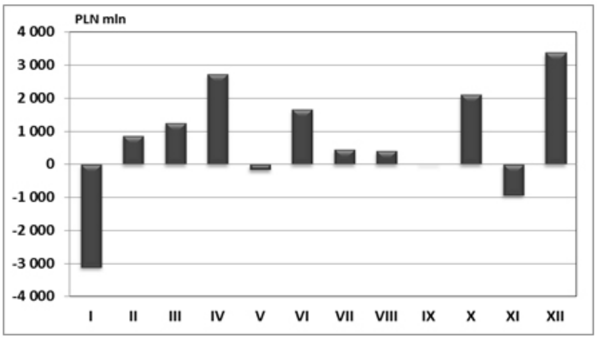
The absorption of CiC from the banking sector takes place in the next month – January is the month, in which significant declines are observed. The characteristics of CiC changes in the consecutive months of a year are presented in Figure 5.

Figure 4: Christmas Effect (in PLN mln)



Source: National Bank of Poland, averaged values

Figure 5: Intra-yearly Effect (in PLN mln)



Source: National Bank of Poland, averaged values

The data and the performance of econometric models

The presented models are estimated on the basis of their sample performance over the period 2 January 2006 – 31 December 2011 and covers 1565 observations. The identified seasonal patterns have been coded as dummy variables. With the use of Akaike Information Criterion (AIC) and Schwarz Information Criterion (SIC) the ARIMA and SARIMA models were chosen. The best results were obtained for ARIMA(2,3) with a constant and SARIMA(2,3)(5,0) also with a constant (Tables 2 – 5). The dummy variables were added both to model ARIMA(2,3) with a constant and to SARIMA(2,3)(5,0) with a constant. In each step of approximation statistically insignificant variables were rejected for p-value greater than 5%. After such a procedure the final structure of econometric models were achieved - ARIMA(2,1) with 15 dummy variables were rejected for p-value greater than 5%. After such a procedure the final structure of econometric models were achieved - ARIMA(2,1) with 15 dummy variables and SARIMA(2,1)(5,0) with 14 dummy variables, the details are presented in Table 6 and Table 7.

For the operational purposes of monetary policy, the daily changes of the CiC level are forecast for the next Reserve Maintenance Period (RMP). RMP covers a period of about a calendar month and ranging from 28 to 33 days (including Saturdays and Sundays, in which increases of CiC are zero). The exact scopes of RMPs the NBP publishes on the TM Reuters side <NBPM> and Bloomberg side <NBP18>. From the point of view of monetary policy purposes the most important is the average change of the CiC level in the given RMP. Thus, the evaluation criterion of models considers absolute average deviation of forecasts from average CiC in the relevant RMPs in 2012 (testing sample). The results of this analysis are presented in Table 8.

Table 2: AIC for ARIMA

AR / MA	0	1	2	3
0	14,61	14,17	14,12	14,13
1	14,26	14,14	14,13	14,12
2	14,13	14,12	14,07	**13,84**
3	14,10	14,08	-	-

Source: Own analysis based on the National Bank of Poland data

Table 3: SIC for ARIMA

AR / MA	0	1	2	3
0	14,61	14,18	14,14	14,14
1	14,27	14,15	14,14	14,14
2	14,14	14,13	14,09	**13,86**
3	14,12	14,09	-	-

Source: Own analysis based on the National Bank of Poland data

Table 4: AIC for SARIMA

AR / MA	0	1	2	3
0	14,63	14,18	14,16	14,17
1	14,37	14,15	14,15	14,16
2	14,24	14,13	14,11	**13,81**
3	14,22	14,09	-	-

Source: Own analysis based on the National Bank of Poland data

Table 5: SIC for SARIMA

AR / MA	0	1	2	3
0	14,51	14,18	14,24	14,24
1	14,17	14,15	14,24	14,24
2	14,04	14,13	14,19	**13,76**
3	14,02	14,09	-	-

Source: Own analysis based on the National Bank of Poland data

Table 6: Structural form of ARIMA(2,1) with dummies (p-value>0,05)

Variable	Coefficient	Std. Error	t-Statistic	p-value
MON	-34,6444	13,9881	-2,4767	0,0134
TUE	-150,8112	12,0994	-12,4643	0,0000
THE	340,7128	12,0896	28,1822	0,0000
FRI	344,3135	13,9921	24,6078	0,0000
D8	139,4481	26,5315	5,2559	0,0000
D9	179,4544	26,5019	6,7714	0,0000
D11	54,0002	26,6761	2,0243	0,0431
D12	92,3697	26,7357	3,4549	0,0006
W3	-229,2878	18,1493	-12,6334	0,0000
W4	-195,0308	18,0708	-10,7926	0,0000
JAN	-77,2023	36,8093	-2,0974	0,0361
APR	139,0221	35,9718	3,8648	0,0001
OCT	92,6260	35,5045	2,6089	0,0092
DEC	171,0496	39,8950	4,2875	0,0000
CHR	-315,9701	43,3921	-7,2818	0,0000
AR(1)	-0,3658	0,0593	-6,1676	0,0000
AR(2)	0,4852	0,0430	11,2911	0,0000
MA(1)	0,9328	0,0501	18,6099	0,0000
R-squared	0,69	Mean dependent var		32,28
Adjusted R-squared	0,68	S.D. dependent var		359,33
S.E. of regression	202,50	Akaike info criterion		13,47
Sum squared resid	63310907	Schwarz criterion		13,53
Log likelihood	-10502,67	Hannan-Quinn criter.		13,49
Durbin-Watson stat	2,00			

Table 7: Structural form of SARIMA(2,1)(5,0) with dummies (p-value>0,05)

Variable	Coefficient	Std. Error	t-Statistic	p-value
MON	-32,1118	12,9847	-2,4730	0,0135
TUE	-148,6879	11,2347	-13,2348	0,0000
THE	342,9037	11,2278	30,5406	0,0000
FRI	346,7897	12,9923	26,6919	0,0000
D8	137,7803	26,3565	5,2276	0,0000
D9	178,6656	26,6886	6,6945	0,0000
D12	59,6815	25,0223	2,3851	0,0172
W3	-230,3040	18,1002	-12,7238	0,0000
W4	-199,7083	18,0442	-11,0677	0,0000
JAN	-87,1576	34,9862	-2,4912	0,0128
APR	131,3890	33,8535	3,8811	0,0001
OCT	88,9140	33,3804	2,6637	0,0078
DEC	189,8807	37,9785	4,9997	0,0000
CHR	-328,5015	43,1454	-7,6138	0,0000
AR(1)	-0,3621	0,0495	-7,3215	0,0000
AR(2)	0,4712	0,0378	12,4579	0,0000
SAR(5)	-0,0864	0,0271	-3,1829	0,0015
MA(1)	0,9319	0,0389	23,9416	0,0000
R-squared	0,69	Mean dependent var		31,95
Adjusted R-squared	0,68	S.D. dependent var		359,66
S.E. of regression	202,29	Akaike info criterion		13,47
Sum squared resid	62976704	Schwarz criterion		13,53
Log likelihood	-10467,43	Hannan-Quinn criter.		13,49
Durbin-Watson stat	2,02			

Source: Own analysis based on the National Bank of Poland data

Table 8: Comparative Analysis of Models' Forecasts

Reserve Maintenace Periods in 2012			ARIMA(2,1)	SARIMA(2,1)(5,0)
	Level of CiC	Change of CiC	Deviation from forecast	
January	110 720	-1 767	-319	-344
February	108 588	-2 132	420	461
March	109 031	443	-563	-585
April	111 476	2 444	-320	-292
May	112 340	864	248	-57
June	113 975	1 635	-1644	-1695
July	114 167	192	-54	-134
August	113 786	-380	-292	-253
September	113 390	-396	19	-3
October	112 810	-580	1735	1647
November	112 761	-49	846	794
December	114 109	1348	-781	-677
Average absolute deviation (in PLN mln)			**603**	**578**

Source: Own analysis based on the National Bank of Poland data

Conclusions

Average absolute deviation for both models stood at around PLN 600 million, which from the perspective of the Polish banking sector this (over) liquidity should be treated as a small value. Excluding June's RMP with a significant increase in the level of CiC at the beginning of this period due to the sports event EURO 2012 (it caused average absolute deviation in June's RMP for over PLN 1 600 millions) these values stood at around PLN 500 million.

The average issue of NBP bills (weighted by maturity) in RMPs of 2012 amounted to PLN 94 559 million (excluding fine-tuning operations, i.e. NBP bills with maturity of less than 7 days). It means that average absolute deviation accounted for less than 0,7% of the average scale of Polish banking sector liquidity in the case of both models. The analysis of the models' performance shows their good predictive properties in situations where the demand for CiC generated by commercial banks as a result of their customers' needs reflects the repeatable and predictable behaviour of human beings.

This paper shows that forecasting Currency in Circulation with the use of ARIMA(2,1) and SARIMA(2,1)(5,0) models with dummy variables reflects repeatable behaviours of cash users and helps in managing liquidity conditions. Moreover both models show good fitness measures. To sum up, these models might be applied for monetary policy purposes as at least supportive tools for banking sector liquidity management and forecasting.

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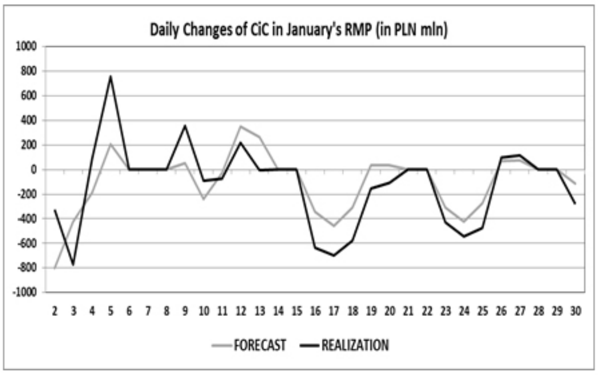
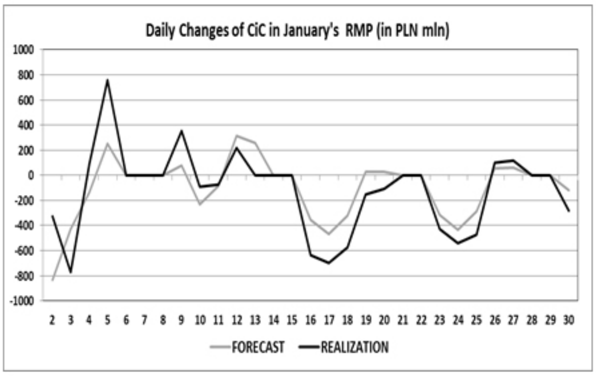
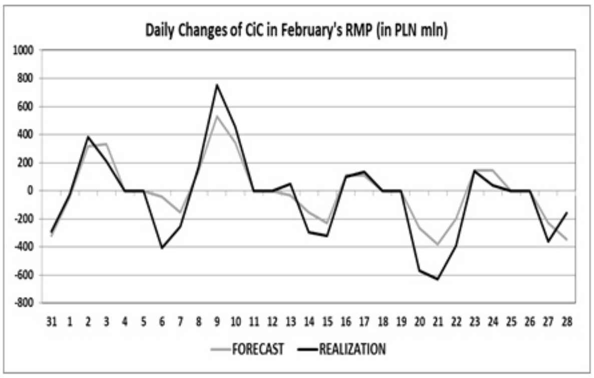
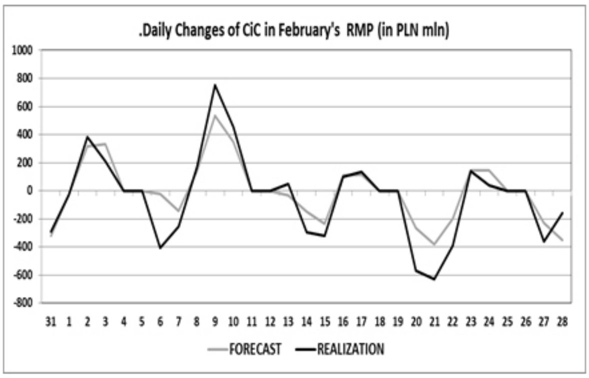
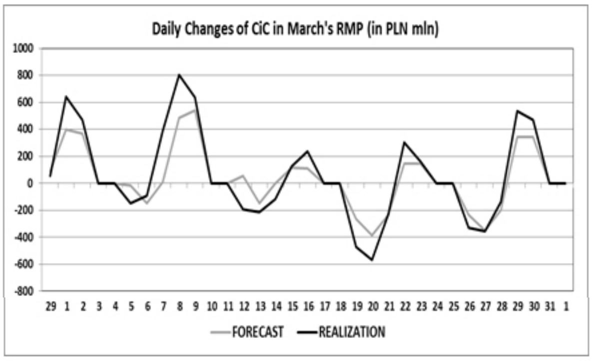
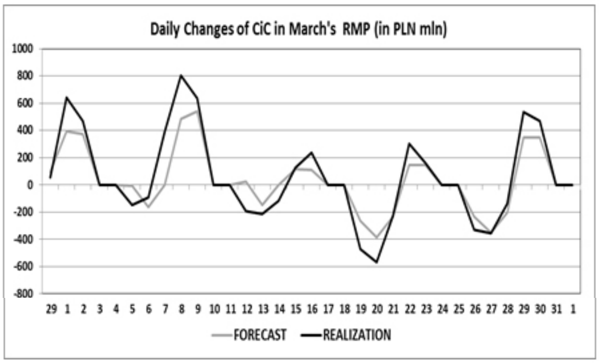
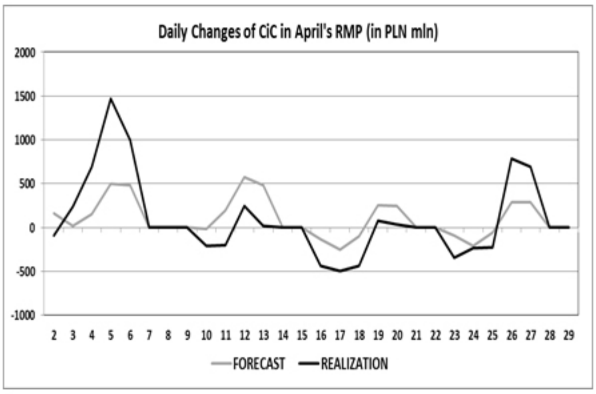
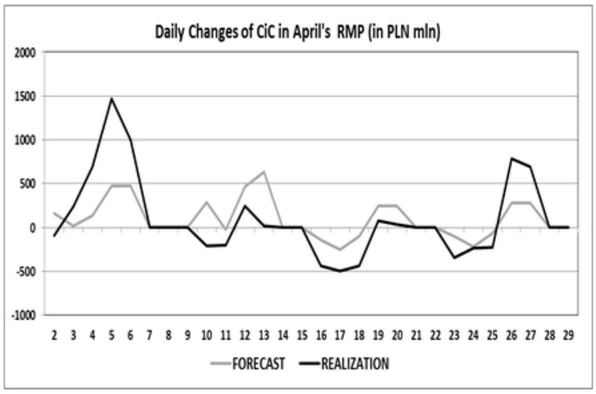
Appendix 1: Forecasts and actual CiC daily changes in the RMPs of 2012

Forecasts of ARIMA(2,1) with 15 dummies	Forecasts of SARIMA(2,1)(5,0) with 14 dummies
	
	
	
	

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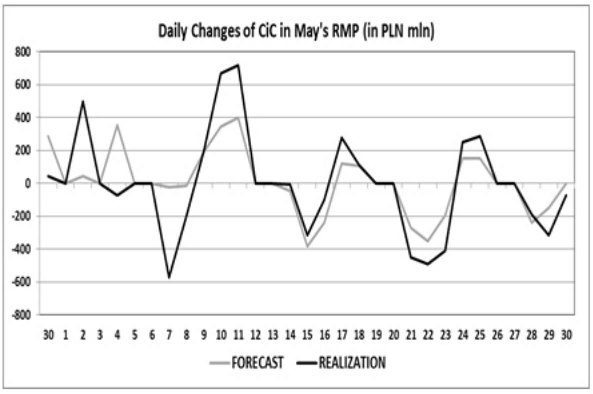
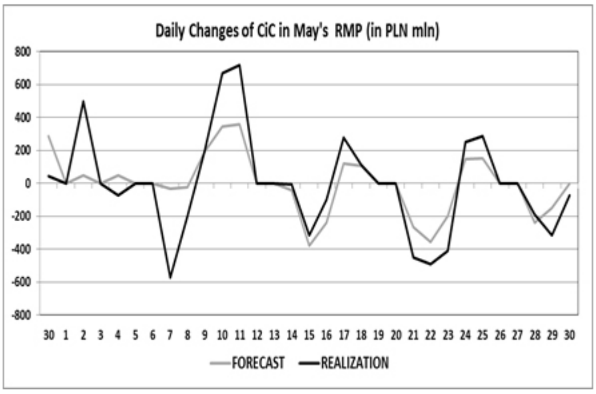
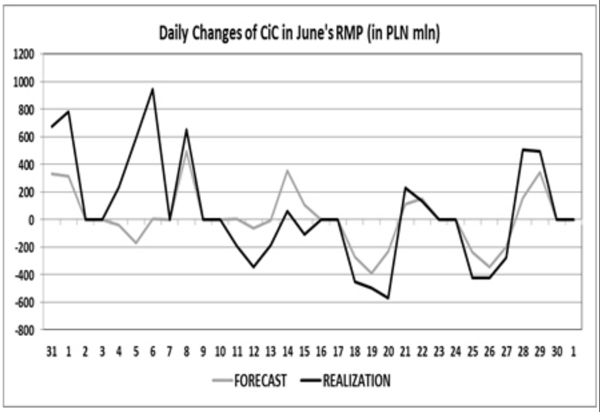
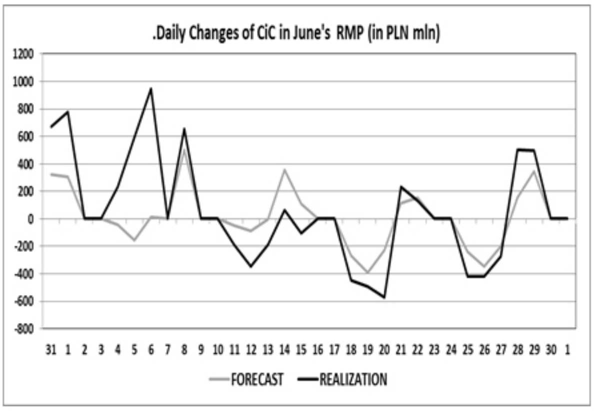
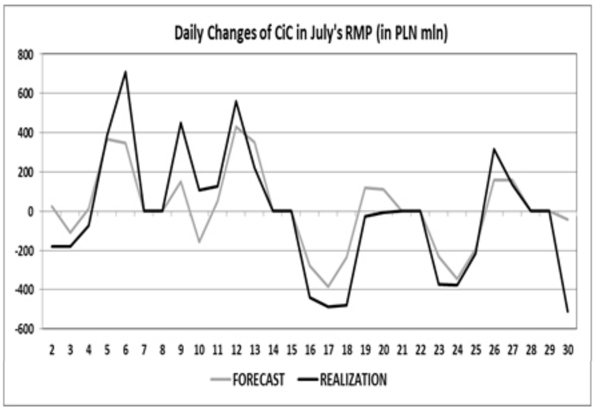
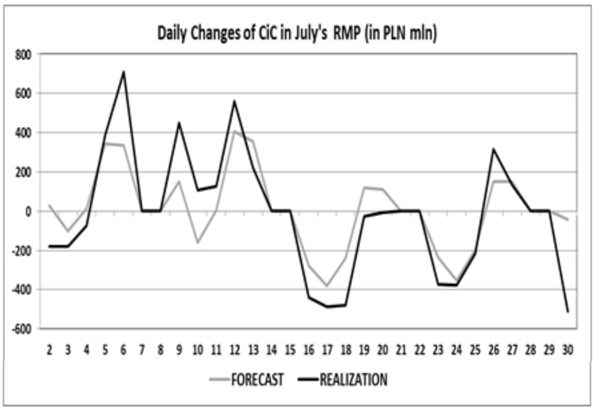
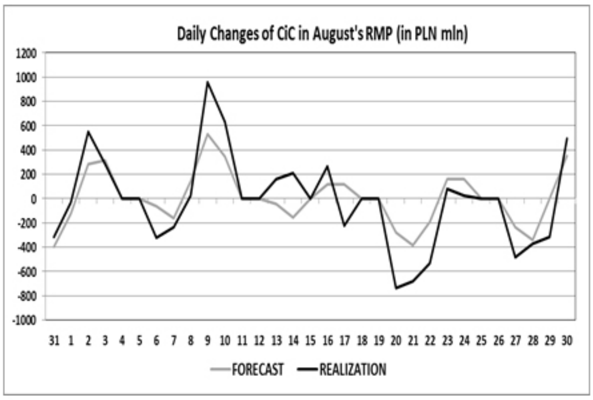
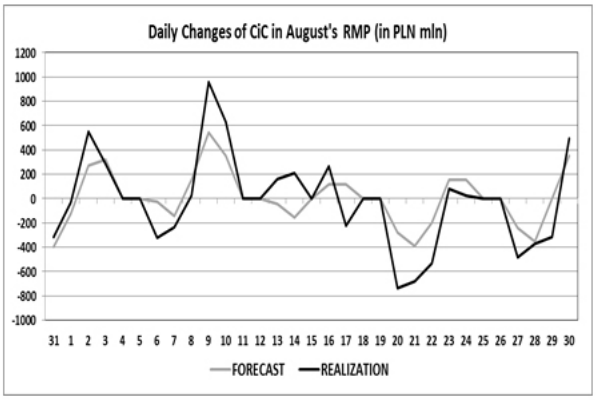
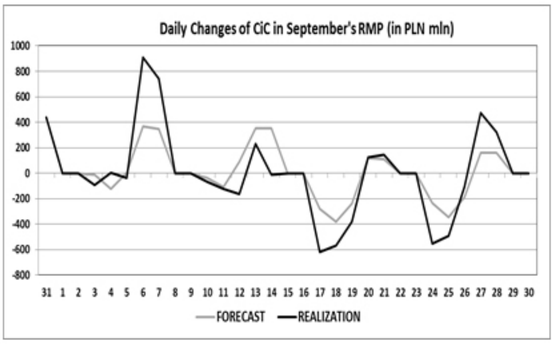
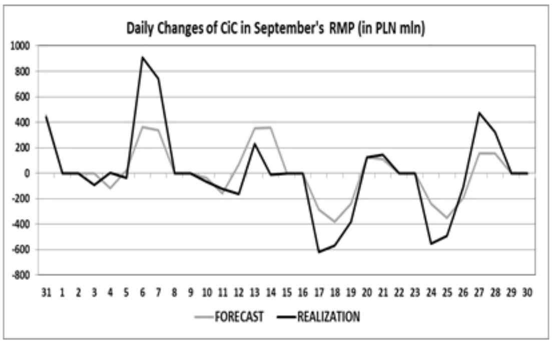
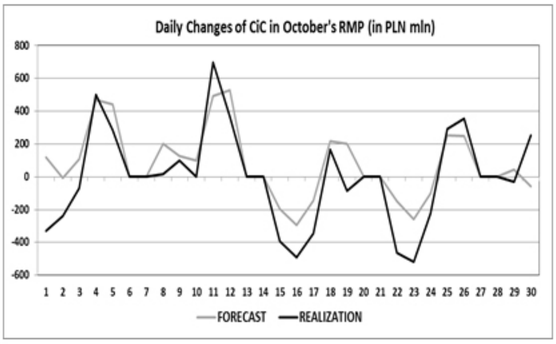
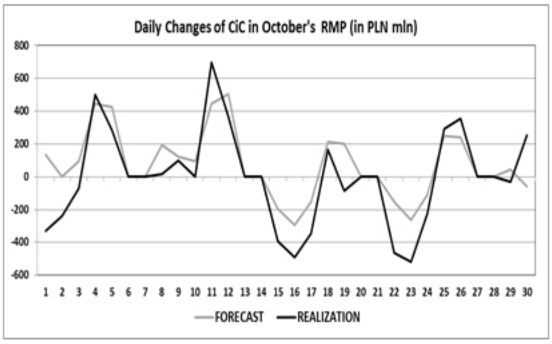
 	
 	
 	
 	

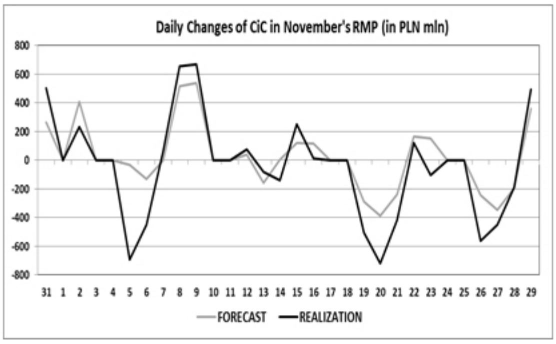
Forecasts of ARIMA(2,1) with 15 dummies	Forecasts of SARIMA(2,1)(5,0) with 14 dummies

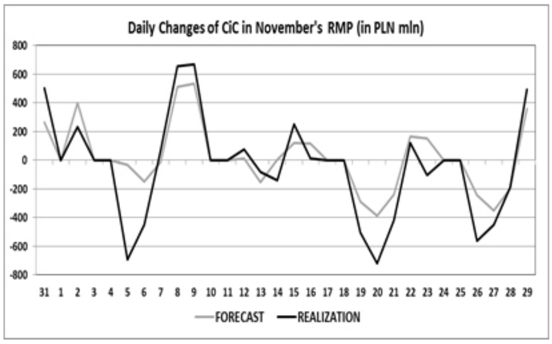


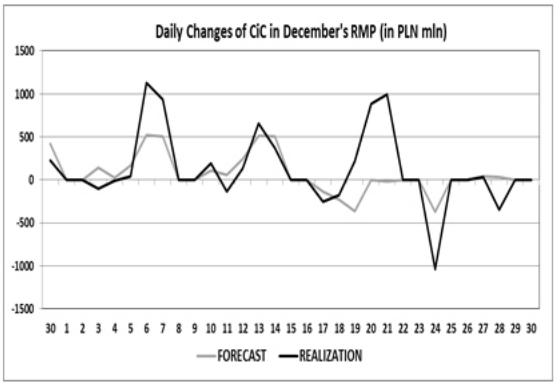


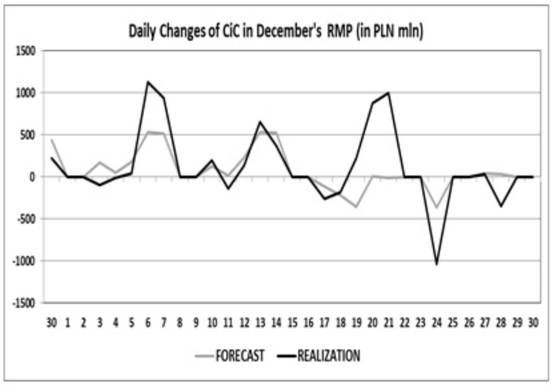




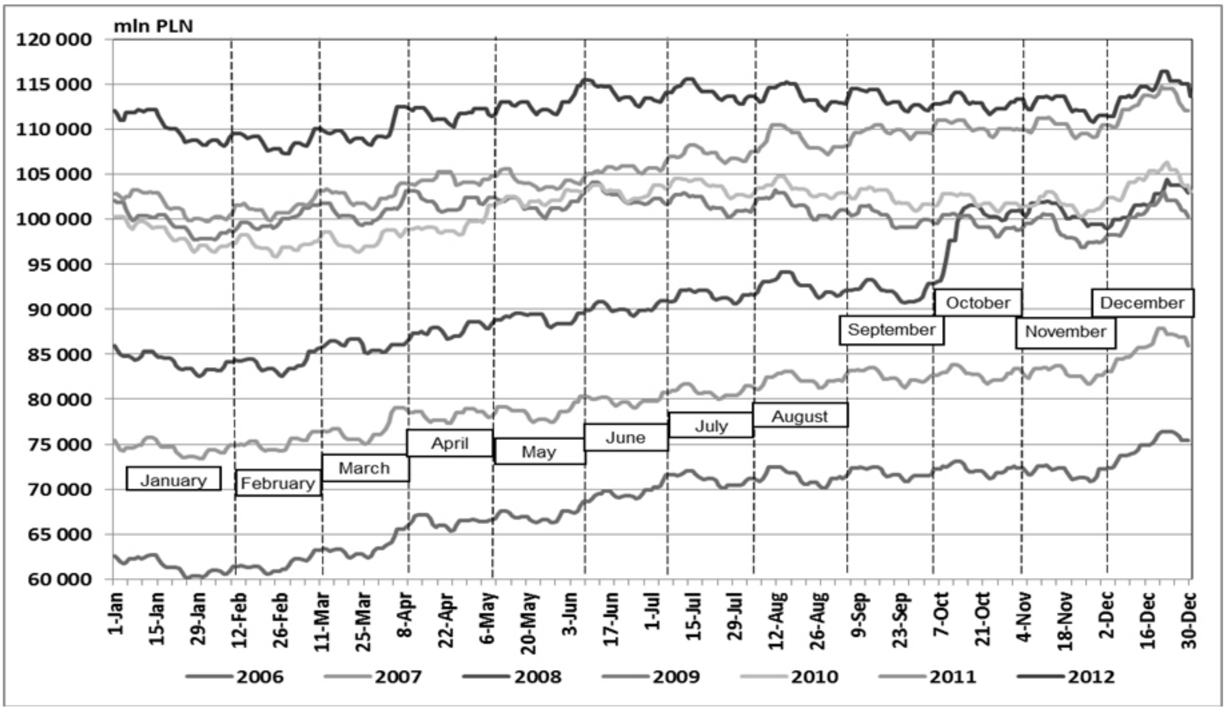








Appendix 2: Currency in Circulation in the years 2006 – 2012 (in PLN mln)



Source: National Bank of Poland (2013). Annual Report 2012. Banking Sector Liquidity. Monetary Policy Instruments of the National Bank of Poland, NBP Press, p. 16