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## Semi-strong informational efficiency in the Polish foreign exchange market

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**Semi-strong informational efficiency in the Polish  
foreign exchange market**

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## **Semi-strong informational efficiency in the Polish foreign exchange market**

**JEL Classification:** *E43, E52, E58, F41, F42, C32*

**Keywords:** *foreign exchange market efficiency, cointegration analysis*

**Abstract:** During the financial crisis a notion that the Polish exchange rate is not determined effectively was very dominant, because of a contagion effect of the global financial crisis on the Polish economy. In addition, many foreign exchange market analysts explained developments in the Polish exchange market through a hypothesis that the Polish zloty exchange rate follows other exchange rates. This contradicts market efficiency as this would lead to profitable arbitrage possibility based on past information on other currency prices and possibly gives a rationale for government intervention. In contrast, a foreign exchange market that is efficient needs no government involvement and its participants cannot earn abnormal gains from foreign exchange transactions. Therefore, the aim of the article is to examine the efficiency of the Poland's foreign exchange market. In order to test for market efficiency a cointegration analysis is used. The main argument builds on the semi-strong form of the market efficiency hypothesis. On an informationally effective market a pair of prices cannot be cointegrated, because this would imply predictability of one asset price based on the past prices of the other asset. The main hypothesis of the article is verified using Unit Root tests and Johansen Cointegration Test on the pair of EURPLN and USDPLN exchange rates. It is shown that the null hypothesis cannot be rejected; therefore, the Polish foreign exchange market is efficient in the semi-strong sense.

### **Introduction**

The answers to questions regarding the form of the efficiency of the foreign exchange markets may be of fundamental importance. These markets are in fact a place where expectations on the overall economy are reflected in currency prices. These expectations, if the market is efficient, provide a valuable signal to business managers and decision-makers, stimulating them to take effective decisions. On an effective market the role

of regulatory bodies is limited. In contrast, if the capital market is inefficient, their investment decisions are *ceteris paribus* more often suboptimal and this can result in significant costs for the economy as a whole. For these reasons, the conclusions drawn from the analysis of the degree of market efficiency can be important both for public authorities and financial institutions, but also for potential investors, especially international investors and market participants.

During the financial crisis the notion that the Polish exchange rate is not determined effectively was very dominant, because of a contagion effect of the global financial crisis on the Polish economy. In addition, many foreign exchange market analysts explain developments in the Polish exchange market through a hypothesis that the Polish zloty exchange follows other exchange rates. This contradicts market efficiency as this would lead to profitable arbitrage possibility based on publicly available information on other currency prices and possibly gives a rationale for government intervention.

Therefore, the aim of the article is to examine the efficiency of the Poland's foreign exchange market. The main argument builds on the semi-strong form of the market efficiency hypothesis (Fama 1970) and is based on a line of reasoning put forward by Granger (1986). On an informatively effective market a pair of prices cannot be cointegrated, because this would imply predictability of at least one asset price based on the past prices of the other asset. This contradicts the market efficiency as this would lead to profitable arbitrage possibility based on past information. The empirical analysis draws on the Johansen (1995) approach. The approach taken in the article was to test for the existence of cointegration between two pairs of daily and monthly Polish zloty foreign exchange rates. The period of observation covers the floating exchange rates of the zloty (2000-2013). It is shown that the null hypothesis can be rejected and, therefore, the Polish foreign exchange market is efficient both in the weak and semi-strong sense.

## **Literature review**

Fama (1970) defines the informational efficiency of the financial market at three levels: weak, semi-strong, and strong forms. The investigation described herein concentrates on the semi-strong form efficiency that stipulates that the current foreign exchange rate not only reflects the historical information but also the information that is publicly available. This hypothesis assumes that foreign exchange rates adjust quickly to absorb new information. Hence, new information cannot be used by anyone for earning abnormal returns. Foreign exchange market informational efficiency can be then considered in two aspects: (i) within-currency

efficiency, and (ii) cross-currency efficiency. The first aspect in the semi-strong efficiency hypotheses concerns mainly forward premium and other fundamental analyses. The second aspect of semi-strong market efficiency examines international linkages across different exchange markets in the long run. The focus of the article was put on the latter market efficiency concept.

The notion of cross-country efficiency of the foreign exchange market can be traced to the articles by MacDonald and Taylor (1989), Hakkio and Rush (1989), and Baillie and Bollerslev (1989). These authors implement the argumentation of Granger (1986) concerning stock market efficiency in the foreign exchange market in order to investigate informational efficiency. The authors' results are mixed and depend on the choice of the method - in the first two articles authors show results of the Engle-Granger procedure supporting the efficient market hypothesis, while the last two authors find support for cointegration in a sample of seven exchange rates using multivariate Johansen procedure. This was confirmed in a large study conducted by Zivot (2000) who tests the foreign exchange market efficiency for the British pound, Japanese yen, and Canadian dollar against the US dollar on a monthly basis from 1976 to 1996 and strongly rejects the efficiency hypothesis in all exchange rates.

The foreign exchange market efficiency subject was first revived upon establishing the European Monetary Union, since it was expected that currencies taking part in the monetary integration would have exhibited mean-reversal behavior towards each other on the approach to forming a common currency. Indeed, Haug, MacKinnon, and Michelis (2000), Rangvid and Sørensen (2002), and Aroskar, Sarkar, and Swanson (2004) find cointegration among the currencies of the first members of the monetary union. In particular, strong confirmation of long-run relationships between exchange rates is present in the period before the introduction of the Euro, in which foreign exchange parities were irrevocably fixed.

The question of market efficiency has been revived for the second time during the 2007-2011 global financial crises, during which investor rationality has been questioned by many commentators. Ahmad et al. (2012) examine the within and cross-country market efficiency for 12 Asia-Pacific foreign currency markets using daily spot and one-month forward exchange rates from 1997 until 2010, and compare the 1997-98 Asian and the global financial crises. Authors conclude that foreign exchange markets are generally efficient from within-country and cross-country perspectives according to their results of Johansen cointegration tests. This study confirms the findings of Pilbeam and Olmo (2011).

Kuhl (2010) tests for cointegration in pairs of daily foreign exchange rates for periods before and after the introduction of the Euro. Only the

Deutsche mark-US dollar and French franc-US dollar are cointegrated before the creation of the EMU. Like other authors, the author attributes this to the monetary integration. However, the introduction of the Euro creates two different cointegration relationships that are between Euro-US dollar and the four most important exchange rates.

The only studies in Polish foreign exchange market efficiency concern much earlier periods Grotowski and Wyroba (2006) and deal with market efficiency in the weak sense. To our knowledge there are no studies concerning the recent period of polish zloty exchange rate instability using cointegration methods.

### Methodology of the research

Consider three countries, each with a single currency following a floating exchange rate regime. This implies three exchange rates for each pair of countries. For the ease of exposition each pair of exchange rates are expressed in the same currency. The exchange rate  $e^{ij}$  can be defined as the price of the domestic currency  $i$  in terms of the foreign currency  $j$  (indirect quotation), where  $i, j=1,2,3$ .

It can be assumed that the expectations regarding the exchange rate  $e_t^{i,j}$  in period  $t$  are based upon publicly available information set  $\Phi_{t-1}^{i,j}$  that includes past realization of this exchange rate:

$$\Phi_{t-1}^{i,j} = \{e_{t-1}^{i,j}, e_{t-2}^{i,j}, e_{t-3}^{i,j} \dots\} \quad (1)$$

This is trivial, however it is straightforward to assume that past realization of *both pairs* of exchange rates to a given domestic currency  $i=1$  are known to the market participants, therefore the information set  $\Phi_{t-1}^1$  for a given currency entails both the information on historical behavior of the exchange rate  $e_t^{1,2}$ , that is  $\Phi_{t-1}^{1,2}$ , and  $e_t^{1,3}$   $\Phi_{t-1}^{1,3}$ . Formally:

$$\Phi_{t-1}^1 = \Phi_{t-1}^{1,2} + \Phi_{t-1}^{1,3} \quad (2)$$

If a market is informational semi-strong cross-efficient, the expectations regarding the exchange rate  $e_t^{1,2}$  are formed using both information sets. It stems from this that:

$$E(e_t^{1,2} | \Phi_{t-1}^{1,2}) = E(e_t^{1,2} | \Phi_{t-1}^1) \quad (3)$$

This allows to put forward the relation of the cross exchange rates in the cointegration framework and relate it to the semi-strong form informational efficiency hypothesis in the empirical model, since the value of other exchange rates in a given currency are known to the market participants.

Let us consider the Johansen procedure to test the existence of cointegration. The exposition follows Goczek, Mycielska (2014).

Assume that the two time series for the exchange rate pairs considered form a bivariate data vector  $\mathbf{X}_t$  given by:

$$\mathbf{X}_t = \begin{pmatrix} e_t^{1,2} \\ e_t^{1,3} \end{pmatrix} \quad (4)$$

The two variables are used to form a Vector Autoregressive (VAR) model described with the following equation:

$$\mathbf{X}_t = \Pi_0 + \Pi_1 t + \sum_{i=1}^K \Pi_i \mathbf{X}_{t-i} + \mathbf{u}_t \quad (5)$$

where the error term  $\mathbf{u}_t \in N(0, \sigma^2)$  is uncorrelated over  $t$ , the data vector  $\mathbf{X}_t$  is of a dimension  $p \times T$ ,  $\Pi_i$  is the deterministic coefficient matrix (intercepts or/and trends) of a dimension  $p \times p + 2$ . If the data are non-stationary in levels and stationary in first differences, then the equation (2) can be rearranged to form a vector error correction mechanism:

$$\Delta \mathbf{X}_t = \Pi^* \mathbf{X}_{t-1}^* + \sum_{i=1}^{K-1} \Gamma_i \Delta \mathbf{X}_{t-i} + \mathbf{u}_t \quad (6)$$

where:  $\mathbf{X}_{t-1}^* = (\mathbf{X}_{t-1}, 1, t)'$ ,  $\Pi^* = (\Pi, \Pi_0, \Pi_1)$ ,  $\Pi = \sum_{i=1}^K \Pi_i - I$  and  $\Gamma_i = -\sum_{j=i+1}^K \Pi_j$ .

The matrices  $\Gamma_i$  contain information on the short-run adjustment coefficients of the lagged differenced variables. Furthermore, the expression  $\Pi^* \mathbf{X}_{t-1}^*$  denotes the error correction term, i.e. it includes the long-run relationships between the time series (Lutkepohl, 2005).

In general, the rank of a matrix shows the number of linearly independent processes that is equivalent to the number of linearly independent columns. According to the assumption that  $\mathbf{X}_t \sim I(1)$  and  $\mathbf{u}_t \sim I(0)$ , both the differences of the endogenous variables and their lagged differences are stationary, thus the matrix  $\Pi$  is of reduced rank for the equation (6) to be balanced. If  $\Pi$  is of reduced rank, then there exists  $p \times r$  matrices  $\alpha$  and  $\beta$  such that  $\Pi = \alpha\beta'$  and the equation (6) can be transformed to:

$$\Delta \mathbf{X}_t = \alpha\beta' \mathbf{X}_{t-1}^* + \sum_{i=1}^{K-1} \Gamma_i \Delta \mathbf{X}_{t-i} + \mathbf{u}_t. \quad (7)$$

The term  $\beta' \mathbf{X}_{t-1}^*$  with  $\beta' = [1, -b]$  is the cointegrating vector showing the steady state relationship between the exchange rates. In the context of exchange rates those are linear combinations, which themselves are non-stationary, but the relationship between them is stationary with a steady state cointegrating vector. In this case, the system shown in equation (7) becomes a vector error correction model and the matrix  $\alpha$  describes the adjustment speed for each variable after it deviates from the long-run relationship. If the matrix  $\Pi$  is of rank one, this means that a single cointegrating vector exists, and  $\beta'$  is  $1 \times p+2$  (deterministic components of the cointegrating relationship). If the rank is in fact one, this means that there exists a single cointegration vector - a single steady state relationship. In the article, three types of methods for determining the number of cointegrating equations. The first is Johansen's "trace" statistic method. The second is his "maximum eigenvalue" statistic method. The third method chooses rank to minimize an information criterion (Akaike or Schwarz-Bayes, although Schwarz-Bayes is probably the more frequent one as it prevents the overparametrization to greater extent – as for example in Witkowski, 2014).

This implies that the estimated error correction term  $(e_{t-1}^{1,2} - b \cdot e_{t-1}^{1,3})$  becomes significant in determining the exchange rate behavior. Using the error correction term, one exchange rate can be predicted by using the other if the long run relationship and past exchange rates are known to the market. This means that causality between the exchange rates runs at least in one direction and past information on the one exchange rate can be used to profitably predict the other. It stems from this, that providing there is cointegration between the exchange rates, the market is not efficient in the weak form.

Unfortunately, a more detailed investigation of the choice of deterministic components of the potential cointegrating equation is only provided by only a few of the authors reviewed in the previous part article. The same critique applies to the number of lags used in the model. The approach taken in this article after Aznar and Salvador (2002) is to develop an unrestricted Vector Autoregressive (VAR) model in order to determine the optimal number of lags using information criteria. As in the lag-length selection problem, choosing the specification of the cointegration equation that minimizes either the Schwarz Information Criterion (SIC) or the Akaike information criterion (AIC) provides a consistent estimator of the steady-state equilibrium. Of the two criteria SIC was the preferred measure, however, changing into AIC did not change the results.

Empirical results follow in the next chapter.



## Empirical model results

In the empirical investigation the EURUSD and the PLNUSD exchange rates with daily and monthly frequency are used during the period starting from April the 1st 2000 to April the 1st 2013. The start date relates to the de facto floatation of the Polish zloty. Figure 1 plots the two variables using a standard normalization procedure. It can be seen from a basic visual inspection of the two series that the stochastic processes generating this data seem to exhibit individual trends ie. the stochastic process guiding the series are not stationary. This is verified by the summary results of unit root tests. Furthermore, a visual inspection of two series makes it possible that the two rates share a common trend. In the case of variables which are integrated of the same order it is possible to investigate the presence of a long-run relationship, which relates to the macroeconomic concept of a steady-state dynamic equilibrium between the two series. This can be determined in the data using tests for the existence of a cointegrating vector for the exchange rates.

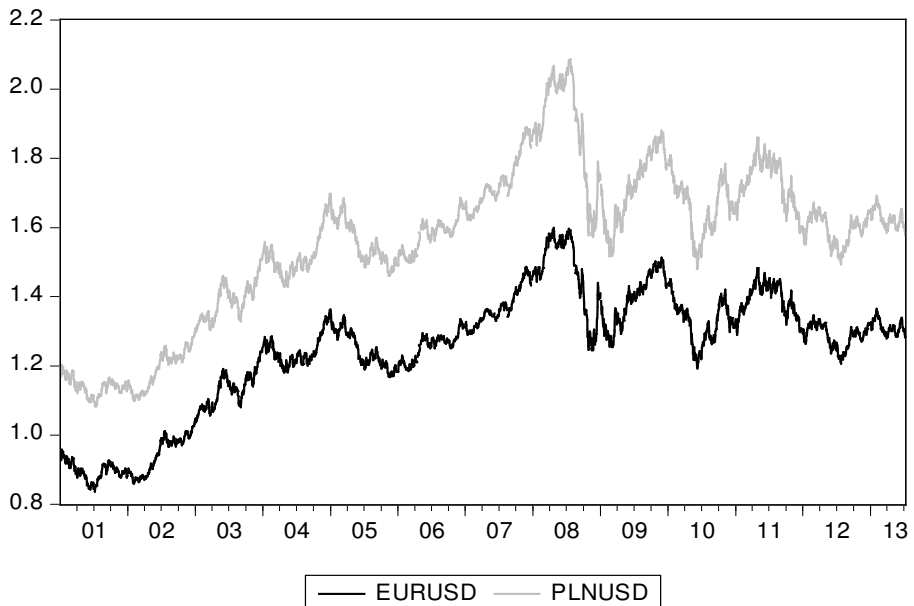


Figure 1. Normalized PLNUSD and EURUSD exchange rates  
Source: Own calculations.

The empirical analysis started with Granger Causality testing to confirm with casual the relations visible in the data. Based on the results, presented in Table 1, it was concluded that there exists a casual relationship between the two variables of interest. Based on these preliminary results it can be hypothesized that EURUSD and PLNUSD exhibit a positive feedback relationship while the USDEUR exchange rate is not influenced by PLNEUR. USDEUR is an exogenous variable that impacts PLNEUR in the Granger sense. These empirical relations point toward the notion expressed at the beginning of the article that many foreign exchange market analysts explained developments in the Polish exchange market through a hypothesis that the Polish zloty exchange rate follows other exchange rates. In this sense, the results are quite straightforward to interpret. While this gives the motivation to develop market efficiency verification argumentation further, it is not in any way a rejection of the efficiency hypothesis, as argued by Ferre and Hall (2010). The authors present a line of argument that if the economy is composed of  $N$  exchange rates and the closed system is analyzed without dynamics, as it is the case when considering the no-arbitrage condition, the Granger causality does not inform about efficiency.

**Table 1.** Pairwise Granger Causality Tests (10 Lags)

Null Hypothesis:	Obs	F-Statistic	P-value
EURUSD does not Granger Cause PLNUSD	3402	22.44138	0.0071
PLNUSD does not Granger Cause EURUSD		9.54662	8.E-16
PLNEUR does not Granger Cause USDEUR	3291	1.31777	0.2145
USDEUR does not Granger Cause PLNEUR		2.07564	0.0232

Source: Own calculations.

As a second step, Unit Roots tests were run. These tests are frequently used in the informational efficiency literature as an indication of market efficiency in the weak form. In this form of efficiency the information set includes all past prices and foreign exchange rates fully and instantly reflect all available historical information. Consequently, a market is said to be weak-form efficient if past exchange rates are useless in predicting future exchange rate. In this sense the prices are to follow a random walk and stochastic processes guiding the series should be non-stationary in levels and stationary in first differences as discussed in Goczek and Kania-Morales (2015).

The tests results for the time series exchange rate in levels and differences are shown in Table 2. The first tests were described previously generalized version of the ADF test of Elliott, Rothenberg and Stock's (1996). The test results for the time series rate in levels and differences are shown in Table 1. Both the number of levels and the number of first differences in applying the Schwert criterion determined to select a maximum number of 29 lags. This is also the number of lags was preferred by the information criteria Ng and Perron sequential t statistic in the case of data in levels. For a number of different data it was also suggested selecting the test criteria of 17 lags. In both cases, the results gave no grounds for rejecting the hypothesis of the existence of a unit root in levels and the null was rejected for first differences. On this basis, it can be assumed that the stochastic process generating exchange rates of the Polish zloty is an I(1) process.

To confirm the degree of integration of the data guiding process, the exchange rates were also tested using Kwiatkowski-Phillips-Schmidt-Shin (KPSS, 1992) stationarity test. The bandwidth of the KPSS was selected according to the Schwert criteria and Bartlett kernel was used to estimate the variance term. Based on the KPSS test results shown in middle rows of Table 2 it can be stated that the stochastic processes of exchange rates are non-stationary, but the results are not as strong as in the previous tests case. Determining the order of integration of the process guiding EURPLN is

quite cumbersome due to the size of the test statistics, which is not clear on the stationarity of the level series used for all standard levels of significance. In particular, the obtained test statistic is between 1% and 5% critical values, and thus depending on the accepted level of significance the stochastic process is either an  $I(0)$ , or  $I(1)$ .

This result was investigated further. It could be that structural breaks in the data are responsible for this result. Therefore inference on the existence of unit root using test by Zivot Andrews with a structural break in the level plus breaks in both the level and trend followed. Zivot-Andrews (1992) test confirms that the stochastic processes guiding both EURPLN and USDPLN are integrated of order one. This suggests that the Polish zloty exchange rate follows a random walk with structural breaks in both intercept and trends, and thus the Polish foreign exchange market is weak-form efficient and past prices are useless in predicting future prices, i.e., technical analysis is of no use for Forex investors.

**Table 2.** Summary of Unit Root Tests

	EURPLN in levels	EURPLN in first differences	USDPLN in levels	USDPLN in first differences
Phillips-Perron test for unit root				
Z(t)	-2.123	-58.78	-2.87	-50.364
MacKinnon p-value	(0.2355)	(0.0001)	(0.0489)	(0.0000)
DF-GLS test				
DF-GLS tau statistic	-2.010	-8.341	-0.749	-3.684
1% Critical	-2.565	-3.48	-2.565	-3.48
5% Critical	-1.940	-2.89	-1.940	-2.834
10% Critical	-1.616	-2.57	-1.616	-2.547
Kwiatkowski-Phillips-Schmidt-Shin test				
KPSS statistic	0.439	0.061	4.112	0.132
1% Critical	0.739	0.739	0.739	0.739
5% Critical	0.463	0.463	0.463	0.463
10% Critical	0.347	0.347	0.347	0.347
Zivot-Andrews unit root test with a break in intercept				
Minimum t-statistic	-2.804	-20.971	-3.568	-17.651
1% Critical	-5.43	-5.43	-5.43	-5.43
5% Critical	-4.80	-4.80	-4.80	-4.80
Zivot-Andrews unit root test with a break both in intercept and trend				
Minimum t-statistic	-2.804	-4.796	-4.796	-27.559
1% Critical	-5.43	-5.43	-5.43	-5.43
5% Critical	-4.80	-4.80	-4.80	-4.80
DGP Integration	~I(1)		~I(1)	

Source: Own calculations.

The analysis of the data generating process went further on to analyze a simple VAR model. The reason for this analysis was to determine the number of lags necessary to perform an effective Johansen Cointegration

test using information criteria. The lag length selection was based on the SIC to penalize large over identified models. Under this criterion lag length of two was selected. Changing into the AIC changed the number of lags to 19 without any impact on the obtained results. Based on this two versions of the Johansen Cointegration Test were run (the trace rank test and the maximum eigenvalue test) in order to determine the rank of the matrix  $\Pi$  for each possible specification of the cointegration equation. The results were summarized in Table 3 listing the number of cointegrating relations by all possible deterministic component models. The results show no significant cointegration in any of the specifications at 0.05 level, though no p-value was lower than 0.2. The lower part of table 3 contains the AIC and BIC information criteria guiding the choice of the deterministic components of the cointegrating relation, as discussed in the methodology section. Again the information criteria show point toward no cointegration in the bivariate vector of exchange rates, however, the model with no intercept in VAR, but with an intercept in cointegrating equation was chosen.

**Table 3.** Johansen Cointegration Test Results

Selected (0.05 level*) Number of Cointegrating Relations by Model					
Data Trend: Test Type	None No Intercept No Trend	None Intercept No Trend	Linear Intercept No Trend	Linear Intercept Trend	Quadratic Intercept Trend
Trace	0	0	0	0	0
Max-Eig	0	0	0	0	0
Information Criteria by Rank and Model					
Data Trend: Rank or No. of CEs	None No Intercept No Trend	None Intercept No Trend	Linear Intercept No Trend	Linear Intercept Trend	Quadratic Intercept Trend
Log Likelihood by Rank (rows) and Model (columns)					
0	14700.29	14700.29	14700.99	14700.99	14701.99
1	14703.57	14703.80	14703.93	14703.95	14704.22
2	14703.58	14705.72	14705.72	14706.19	14706.19
Akaike Information Criteria by Rank (rows) and Model (columns)					
0	-9.194289*	-9.194289*	-9.193470	-9.193470	-9.192841
1	-9.193837	-9.193351	-9.192804	-9.192195	-9.191734
2	-9.191332	-9.191421	-9.191421	-9.190458	-9.190458
Schwarz Criteria by Rank (rows) and Model (columns)					
0	-9.118185*	-9.118185*	-9.113560	-9.113560	-9.109126
1	-9.110122	-9.107733	-9.105284	-9.102772	-9.100409
2	-9.100006	-9.096290	-9.096290	-9.091522	-9.091522

Source: Own calculations.

\* denotes rejection of the hypothesis at the 0.05 level

Table 4 lists the results of both Johansen Cointegration tests with the chosen model specification. No steady state cointegrating relationship was found with a very large statistical significance. This precludes any possible errors coming from the "noise" from daily frequency of observations. Similar tests were run for monthly data obtaining the same results. This confirms the main hypothesis of the article - there is no relation between Polish zloty exchange rates and the Poland's foreign market is informatively efficient in the semi-strong sense.

**Table 4.** Johansen Cointegration Test Results - full sample

Unrestricted Cointegration Rank Test (Trace)				
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None	0.002195	10.85155	20.26184	0.5565
At most 1	0.001204	3.842845	9.164546	0.4360
Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None	0.002195	7.008703	15.89210	0.6684
At most 1	0.001204	3.842845	9.164546	0.4360

Source: Own calculations.

\* denotes rejection of the hypothesis at the 0.05 level

\*\*MacKinnon-Haug-Michelis (1999) p-values

The obtained results have been checked for robustness. As already mentioned both daily and monthly data were analyzed to account for the noise generated in daily data. Moreover, different pairings of exchange rates with zloty were used, however, with no change in the results (as expected due to arbitrage possibility). In addition, the sample was cut into smaller subsamples to account for the possibility of contagion in of the global financial crisis to the Polish market. The crisis interval was set from beginning of 2008 to 2010 and the whole analysis was re-run to verify the any possible contagion effect that would show through market inefficiency. Again, there are no grounds to believe that the semi-strong efficiency of the Polish zloty is violated.



**Table 5.** Johansen Cointegration Test Results - financial crisis period (2008-2010)

Unrestricted Cointegration Rank Test (Trace)				
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None	0.015665	11.56604	20.26184	0.4885
At most 1	0.007088	3.592362	9.164546	0.4762
Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None	0.015665	7.973679	15.89210	0.5509
At most 1	0.007088	3.592362	9.164546	0.4762

Source: Own calculations.

\* denotes rejection of the hypothesis at the 0.05 level

\*\*MacKinnon-Haug-Michelis (1999) p-values

The analysis was carried out also with other crisis time-spans with no difference in results. For all tested sub-periods market efficiency cannot be rejected. It seems that the Polish zloty market continues to be semi-strongly efficient even in times of crisis - a trait characteristic of the most liquid currencies in the world.

## Conclusions

In this article, the Polish zloty foreign exchange market is tested for cointegration in pairs of daily foreign exchange rates for periods before and after the financial crisis in order to test semi-strong informational market efficiency. The main hypothesis of the article has been confirmed. It is shown that the null hypothesis of no cointegration cannot be rejected. As a result, it can be argued that the financial crisis has not resulted in a cross-sectionally inefficient foreign exchange market for the Polish zloty, because the cointegration relationships were not found in any of the investigated crisis sub-periods.

Confirmation of the weak and semi-strong efficiency of the market is a prerequisite for an average investment profitability based on analyzes that measure the intrinsic value of the assets of the designation (such as broadly defined fundamental analysis based on other exchange rates) and those based solely on the analysis of graphs and historical data on asset prices (broadly defined technical analysis) alike and from the point of investors these instruments are of no use. In this sense, however, there is no rationale for government intervention in the market as it allows taking optimal investment

decisions. However, only a subset of the whole spectrum of tests on the effectiveness of information in foreign exchange market has been carried out and this still remains open for future research.

## References

- Ahmad, R., Rhee, S.G. & Wong, Y.M.J., (2012). Foreign Exchange Market Efficiency Under Recent Crises: Asia-Pacific Focus. *SSRN Electronic Journal*. Available at: <http://dx.doi.org/10.2139/ssrn.1913995>.
- Aroskar, R., Sarkar, S. K., & Swanson, P. E. (2004). European foreign exchange market efficiency. Evidence based on crisis and non crisis periods. *International Review of Financial Analysis*, 13(3), 333–347.
- Aznar, A. & M. Salvador. (2002). Selecting the rank of the cointegration space and the form of the intercept using an information criterion. *Econometric Theory*, 18: 926–947. <http://dx.doi.org/10.1017/s0266466602184064>
- Baillie, R. T., & Bollerslev, T. P. (1989). Common stochastic trends in a system of exchange rates, *The Journal of Finance*, 44(1), 167–18. <http://dx.doi.org/10.1111/j.1540-6261.1989.tb02410.x>
- Elliott, G., Rothenberg, T.J. & Stock, J.H., (1996). Efficient Tests for an Autoregressive Unit Root. *Econometrica*, 64(4), p.813. Available at: <http://dx.doi.org/10.2307/2171846>.
- Fama, E. F. (1970). Efficient Capital Markets: A Review of Theory and Empirical Work. *The Journal of Finance*, Vol. 25:383–417. <http://dx.doi.org/10.2307/2325486>
- Ferré, M. & Hall, S.G., 2002. Foreign exchange market efficiency and cointegration. *Applied Financial Economics*, 12(2), pp.131–139. Available at: <http://dx.doi.org/10.1080/09603100110090055>.
- Goczek, Ł. & D. Mycielska (2013). Ready for euro? Empirical study of the actual monetary policy independence in Poland”, *WNE Working Papers*
- Goczek, L., Mycielska D., (2014). "Gotowi na euro? Badanie empiryczne faktycznej swobody polskiej polityki pieniężnej", *Bank i Kredyt*, 45(3), pp. 267-290.
- Goczek, Ł. & J. Mycielski (2013). Modelowanie stóp procentowych w Polsce - testy istnienia pierwiastka jednostkowego ze strukturalnym załamaniem," [in:] *Innowacje i implikacje interdyscyplinarne*, red. Zbigniew Zieliński PITWIN, Kielce, 2013.
- Goczek, Kania Morales (2015) Analiza porównawcza efektywności rynków papierów wartościowych, ze szczególnym uwzględnieniem kryzysu lat 2007-2009, *Bank i Kredyt*, forthcoming..
- Granger, C.W.J. (1986). Developments in the Study of Cointegrated Economic Variables. *Oxford Bulletin of Economics and Statistics*, Vol. 48:213–228. <http://dx.doi.org/10.1111/j.1468-0084.1986.mp48003002.x>
- Grotowski, M. & K. Wyroba, (2004). Efektywność informacyjna polskiego rynku walutowego - analiza wstępna", *Bank i Kredyt*, nr 1, pp. 65--79.

- Gruszczyński, M. & Stokłosa, M., (2006). Efektywność nieoficjalnego rynku walutowego w Polsce w latach 1982-1989, *Bank i Kredyt*, nr 9, pp. 33--46.
- Hakkio, C. S., & Rush, M. (1989). Market efficiency and cointegration. An application to the sterling and deutschmark exchange markets. *Journal of International Money and Finance*, 8(1), 75–88. [http://dx.doi.org/10.1016/0261-5606\(89\)90015-6](http://dx.doi.org/10.1016/0261-5606(89)90015-6)
- Haug, A. A., MacKinnon, J. G., & Michelis, L. (2000). European Monetary Union. A cointegration analysis. *Journal of International Money and Finance*, 19(3), 419–432. [http://dx.doi.org/10.1016/S0261-5606\(00\)00013-9](http://dx.doi.org/10.1016/S0261-5606(00)00013-9)
- Johansen, S. (1995). *Likelihood-based inference in cointegrated vector autoregressive models. Advanced texts in econometrics*. Oxford: Oxford Univ. Press.
- Juselius, K. (2007). *The Cointegrated VAR Model: Methodology and Applications, Advanced Texts in Econometrics*, Oxford University Press, Oxford.
- Kwiatkowski, D., Phillips, P. Schmidt & P., Shin, Y. (1992). Testing the null hypothesis of stationarity against the alternative of a unit root: How sure are we that economic time series have a unit root?, *Journal of Econometrics*, 54, issue 1-3, str. 159-178. [http://dx.doi.org/10.1016/0304-4076\(92\)90104-y](http://dx.doi.org/10.1016/0304-4076(92)90104-y)
- Kühl, M., (2010). Bivariate cointegration of major exchange rates, cross-market efficiency and the introduction of the Euro. *Journal of Economics and Business*, 62(1), pp.1–19. <http://dx.doi.org/10.1016/j.jeconbus.2009.07.002>.
- Lutkepohl, H. (2005). *New Introduction to Multiple Time Series Analysis*. New York: Springer
- MacDonald, R., & Taylor, M. P. (1989). *Foreign exchange market efficiency and cointegration. Some evidence from the recent float. Economics Letters*, 1, 63–68. [http://dx.doi.org/10.1016/0165-1765\(89\)90174-2](http://dx.doi.org/10.1016/0165-1765(89)90174-2)
- MacKinnon, J. G. (1991). Critical values for cointegration tests in long-run economic relationships. In R. F. Engle, & C. W. J. Granger (Eds.), *Readings in Cointegration* (pp. 267–276). New York: Oxford Univ. Press.
- Olmo, J. & Pilbeam, K., (2011). Uncovered interest parity and the efficiency of the foreign exchange market: a re-examination of the evidence. *International Journal of Finance & Economics*, 16(2), pp.189–204. Available at: <http://dx.doi.org/10.1002/ijfe.429>.
- Rangvid, J. & Sorensen, C. (2002). Convergence in the ERM and Declining Numbers of Common Stochastic Trends. *Journal of Emerging Market Finance*, 1(2), pp.183–213. Available at: <http://dx.doi.org/10.1177/097265270200100203>.
- Witkowski, B. (2014), Spatially weighted model of  $\beta$ -convergence with Eurozone-corrected weights, in K. Opolski & J. Gorski (Eds.) *Perspektywy i wyzwania integracji europejskiej* (pp. 133-144). Warsaw: National Bank of Poland & WNE
- Woo, K.-Y. (1999). Cointegration analysis of the intensity of the ERM currencies under the European Monetary System. *Journal of International Financial Markets, Institutions & Money*, 9(4), 393–405. [http://dx.doi.org/10.1016/S1042-4431\(99\)00016-5](http://dx.doi.org/10.1016/S1042-4431(99)00016-5)

- Zivot, E., & Andrews, D. W. K. (1992). Further evidence on the great crash, the oil-price shock, and the unit root hypothesis. *Journal of Business and Economic Statistics*, 10(3), 251–270. <http://dx.doi.org/10.1080/07350015.1992.10509904>
- Zivot, E., (2000). Cointegration and forward and spot exchange rate regressions. *Journal of International Money and Finance*, 19(6): 785-812  
[http://dx.doi.org/10.1016/s0261-5606\(00\)00031-0](http://dx.doi.org/10.1016/s0261-5606(00)00031-0)