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Collegium of Economic Analysis

Modeling and forecasting of emerging markets' exchange rates – varied influence of domestic and global factors

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1. Introduction and research justification

The foreign exchange market is one of the most important financial markets, with a trading volume exceeding any other (Hong et al., 2007). Gona and Sahoo (2020) point out that the exchange rate is a key financial variable that influences the decisions made by investors, importers, exporters, financial institutions, entrepreneurs, policy makers and tourists. Due to the important role of exchange rates for many market participants, Groen and Matsumoto (2004) emphasize that forecasting exchange rates is a particularly important issue.

Meese and Rogoff, in the seminal 1983 work, showed that exchange rates behaviour is similar to the random walk process, and that classes of exchange rate models used at that time did not give forecasts superior to the so-called naive forecast (a random walk without a drift). The same conclusions were repeated in the later studies for ever wider classes of models. Rossi (2013) reviewed the literature regarding predictability of exchange rates: forecast accuracy differs depending on the choice of forecast horizon, time sample, frequency of data, currency pairs and the method of measuring forecast quality. In most cases, the models are not able to consistently beat the naive forecast. According to recent research, some classes of models allow to obtain accurate forecasts of exchange rates in selected cases – including the half-life PPP model developed by Ca'Zorzi and Rubaszek (2020), models using the Taylor rule (Byrne et al. 2016) or models with time-varying parameters (Abbate, Marcellino 2018). However, these tools are not universal, and their quality depends on the conditions of their evaluation. Emerging markets' exchange rates are particularly volatile, making forecasting more difficult. Therefore, methods showing favorable results in this area are particularly desirable.

Co-movement in the financial markets, i.e., the existence of a strong relationship between the prices of the same or different classes of assets in many markets, is an issue often discussed in the literature. Initially, in the 1950s and 1960s, the co-movement in the international capital market was relatively small (Grubel, 1968; Levy and Sarnat, 1970; Solnik, 1974). Morana and Beltratti (2008) showed that along with the progressing integration of international financial markets, the phenomenon of co-movement intensified. Kamara et al. (2008), Bua and Trecroci (2017) pointed out that with the beginning of the new millennium, financial markets are increasingly exposed to global shocks.

In the era of increasing internationalization, mechanisms related to global capital flows play an increasingly important role in shaping the exchange rates. Particularly noteworthy is the article by Rey (2015), with a research hypothesis of a global cycle of capital flows, asset prices and credit. Countries with a large inflow of foreign capital, i.e., mainly emerging markets, are most susceptible to this cycle. The author of the study showed that this global cycle of capital flows is not related to the economic fundamentals of individual countries but results from changes in global risk aversion.

In the context of co-movement, the literature emphasizes the significant impact of global sentiment on the exchange rates. Fama (1984), Dumas and Solnik (1995) and Hodrick (1989) emphasize the importance of global risk aversion in the analysis of exchange rates. Hopper (1997) noted that exchange rates are primarily influenced by market sentiment, not by the economic situation. Cairns et al. (2007) show that most currencies exhibit significant volatility.

The literature on the subject indicates that the phenomenon of co-movement intensifies in times of turmoil on financial markets. Menkhoff et al. (2012) pointed out that the increased volatility in the currency market leads to a depreciation of the currencies of countries with relatively higher interest rates, i.e., mainly emerging economies. Liu et al. (2012) noticed that in a period of increased volatility there is a risk of a sharp and significant depreciation, especially of currencies with relatively high interest rates.

The literature review presented above highlights three crucial features of emerging market exchange rates: first, the importance of their forecasts for many market participants; second, difficulties in forecasting them; third, the significant influence of global factors on the evolution of exchange rates. The doctoral dissertation combines these three aspects. The conclusions presented in the dissertation constitute a contribution to the existing literature on modeling and forecasting exchange rates.

2. Research objectives and hypotheses

The objective of the doctoral dissertation was to propose novel methods that allow to improve the accuracy of point- and density forecasts of emerging markets' exchange rates. This was achieved after analyzing the varied influence of global and domestic factors on the evolution of the exchange rates and taking that into account while constructing the forecasting algorithms.

In the doctoral dissertation, the following hypotheses were verified:

1. After the outbreak of the global financial crisis, the sensitivity of Central and Eastern European currencies to domestic business cycles decreased, whereas the importance of global factors increased.
2. Changes in global risk aversion cause distortions (namely, a one-directional error) of professionals' forecasts of emerging market exchange rates.
3. Taking into account the impact of changing global market sentiment on emerging market exchange rates leads to density forecasts superior to those from a random walk model.
4. Pressure from other countries is an external factor which may have a significant impact on the evolution of an emerging market currency.
5. In recent years, domestic factors have once again played an important role in shaping the exchange rates of Central and Eastern European countries, and this should be taken into account when modeling and forecasting them.

3. Main results

The structure of the dissertation reflects the abovementioned research hypotheses. Each of them is verified in one scientific article. As a result, the dissertation took the form of a collection of thematically consistent five articles, including one accepted for publication in the journal with the Impact Factor and indexed in the Journal Citation Reports database. A summary of the research conducted within each publication is presented below.

3.1 An increased importance of global factors in shaping the exchange rates of Central and Eastern European currencies after the outbreak of the global financial crisis

The collection of thematically consistent articles begins with the publication entitled "Global financial crisis and costs of losing the independent monetary policy in selected Central and Eastern European countries", published in the *Ekonomista* journal (Borowski, Jaworski, 2015). The starting point for this research was the observation of several stylized facts regarding the exchange rate developments after the outbreak of the global financial crisis in 2008.

The global financial crisis caused significant fluctuations in economic activity in four countries of Central and Eastern Europe, with an independent monetary policy under the floating exchange rate regime (Czech Republic, Poland, Romania, Hungary – CEE-4). In the first phase of the crisis (in 2008-2009), the central banks of the CEE-4 countries significantly lowered nominal interest rates, which contributed to their decline in real terms, lowering the cost of capital and boosting domestic demand. Moreover, in that period there was a strong increase in global risk aversion, which was reflected in a sharp outflow of portfolio capital from bond and equity markets in countries belonging to the so-called emerging markets. This contributed to a strong weakening of the CEE-4 currencies and improved price competitiveness, allowing partial absorption of the negative shock in the form of a decline in external demand. In other words, in the initial phase of the crisis, the currencies of the CEE-4 countries depreciated mainly because investors were selling risky assets, and not due to cuts in domestic interest rates by central banks (due to interest rate cuts in the core markets, the interest rate disparity in the CEE-4 countries did not change significantly).

In the second phase of the crisis, which took place in 2012-2013, the structure of the monetary policy impulse (the exchange rate channel versus the interest rate channel) was different from that observed in 2008-2009. This difference is well illustrated by the example of Poland, where the interest rate disparity decreased much more significantly: this resulted mainly from the difficulty to implement further interest rate cuts in the euro area, where they reached a level close to zero. On the other hand, the PLN exchange rate depreciated to a lesser extent than in the first phase of the crisis, which resulted from the sustained increase in demand for risky assets in that period. The main source of this demand was the quantitative easing programs, implemented by some central banks (including the US Federal Reserve), consisting of the purchase of assets (Treasury bonds and mortgage-backed securities) maintained at a constant monthly level. Moreover, the Federal Reserve's announcement of keeping the federal funds rate close to zero "for an extended period of time" (the so-called forward guidance) supported the persistence of low long-term yields of US Treasury bonds, thus increasing demand for higher-yielding debt of emerging market countries. As a result, despite a sharp reduction in the NBP reference rate, the PLN exchange rate did not weaken significantly. The above observations signal the declining influence of monetary policy on the exchange rate developments in periods of turmoil in the world economy and adjustments in the monetary policy of the Federal Reserve.

In order to verify the hypothesis regarding the decreasing impact of the domestic output gap on the exchange rate of the CEE-4 countries, eight econometric models with the same

structure were built – two for each of the four countries mentioned – and estimated on a full and shortened sample. The endogenous variable in each of the models is the nominal exchange rate of a given country vs. the euro (EURPLN, EURCZK, EURRON, EURHUF). The exchange rate changes were explained by the fluctuations of the domestic output gap and variables reflecting global risk aversion (stock indices and long-term interest rates).

Although the results indicate a statistically significant impact of the domestic output gap on the exchange rate in the full sample (2000-2013), in the models estimated on a shorter sample (2005 Q4–2013 Q2) the cyclical component turned out to be statistically insignificant or the coefficient of determination (R^2) significantly decreased. The results were interpreted as a decrease in the importance of local business cycles as factors shaping the CEE-4 exchange rates, in favor of a relative increase in the importance of global factors (represented in the models by stock indices and the disparity of long-term interest rates) after the outbreak of the global financial crisis.

3.2 Changing global risk aversion and errors of professionals' forecasts of emerging market exchange rates.

The results of the first study (Borowski, Jaworski, 2015), indicating importance of changes in global risk aversion in the shaping emerging markets' exchange rates (Borowski, Jaworski, 2015), prompted me to check whether global factors also contribute to the intensification of forecast errors regarding these exchange rates. The aim of the second article was to investigate empirically how changes in global risk aversion affect the accuracy of professionals' forecasts of exchange rates. The article entitled "Impact of changing global risk aversion on professionals' exchange rate forecasts in the context of increasing internationalization of financial markets" was published in the journal *Studia Ekonomiczne. Zeszyty Naukowe Uniwersytetu Ekonomicznego w Katowicach* (Jaworski, 2018).

Expectations about the future value of exchange rates are crucial for market participants, such as financial market investors and companies that export or import goods. In shaping these expectations, especially important are exchange-rate forecasts prepared by experts – financial market professionals, bank analysts and other research institutions – due to their high credibility. MacDonald (2000), Jongen et al. (2008) reviewed the literature on professionals' exchange rate forecasts and found that in the short term their expectations had a low forecasting capacity. The quality of expert forecasts improves significantly with a longer forecast horizon. Beckmann and Czudaj (2017) indicate that errors in expert forecasts increased significantly after the collapse of Lehman Brothers.

In our analysis, professionals' forecasts of exchange rates were obtained from the Thomson Reuters database. At the beginning of each month, Thomson Reuters collects – from a large number of banks, financial institutions, research centers and individual market analysts – their forecasts of exchange rates over a horizon of one, three, six and twelve months. The median of these individual forecasts, calculated for each horizon, represents market expectations (hereinafter: market consensus). By comparing these expectations with the actual realization of exchange rates (at the end of the given month), we can determine the errors of

analysts' forecasts. In the analysis, I used the market consensus from 2013-2018 concerning the four time horizons mentioned above for 18 emerging markets' currencies vs. the US dollar.

First, I analyzed the evolution of market consensus in relation to the ex post realization of exchange rates. If the hypothesis about the efficiency of financial markets was true and analysts' expectations unbiased, the percentage of currency pairs, for which professionals' exchange rate forecasts show a tendency to miss the target in the same direction (overshooting or undershooting vs. the ex post observation) would be approx. 50%. In other words, on average, half of analysts' forecasts would be too high and the other half – too low. In fact, the situation is quite different. In the case of one-month forecasts, analysts were wrong in the same direction on average for 73.3% of currency pairs. For the 3-month time horizon, this percentage was 74.2%, for the 6-month horizon it was 76.0%, and for the yearly horizon – 63.3%. The results showing that analysts are wrong in the same direction for most currency pairs suggests that the underlying cause of this phenomenon is a common global factor.

Next in the article I showed, using econometric modeling, that changes in global risk aversion are a factor causing those one-directional error in analysts' forecasts. The increase in risk aversion contributes to the intensification of the mean-reverting property of analysts' forecasts – i.e. the expectation of a reversal of trends in the foreign exchange market. Moreover, the analysts' bias (i.e. systematically too high or too low forecasts compared to their ex-post realization) occurs not only for a single exchange rate but simultaneously for multiple currency pairs. This error is one-directional and has a common origin – it intensifies as the risk aversion increases. Such results are particularly interesting, if we take into account the fact that expert forecasts for different exchange rates are prepared separately by different people and institutions. The occurrence of a one-directional error simultaneously for many currency pairs is therefore not caused by one person's erroneous (biased) expectations of general market conditions. The reason for such a phenomenon is therefore a common global factor.

3.3 Taking into account the changing global risk aversion while forecasting emerging markets' exchange rates

The obtained results indicating distortions of professionals' forecasts of exchange rates due to the changing global risk aversion (Jaworski, 2018) indicated a need to develop a forecasting method robust to such errors. The article "Sentiment-induced regime switching in density forecasts of emerging markets' exchange rates. Calibrated simulation trumps estimated autoregression", presenting such a model, was published in the journal *Bank & Credit* (Jaworski, 2019).

The objective of the article is to propose a novel method to generate density forecasts of emerging markets' exchange rates. A density forecast represents a complete characterization of the uncertainty associated with the forecast, as opposed to a point forecast, which provides no information about the uncertainty of the prediction. This property is crucial in regard to financial markets' indicators – it allows to account for "fat tails" of the distribution, estimate portfolio risk, etc.

The underlying assumption of the analysis is that financial markets on each day are in one of three states (regimes) corresponding to investors' sentiment – (1) elevated risk aversion

(so-called "risk-off"), (2) low risk aversion ("risk-on"), or (3) a neutral state. In the first state, market participants usually tend to escape towards so-called save heavens, i.e. lower-risk investments, which, among other things, leads to weakening of emerging markets' currencies. In the second regime we observe an opposite situation. When risk is perceived as low, market participants have a tendency to participate in higher-risk investments, which leads to strengthening of emerging markets' currencies. The third, neutral regime indicates a state of a moderate risk aversion. To determine the regime on the particular day, the value of the Chicago Board Option Exchange Volatility Index (i.e. the VIX index, dubbed the "fear gauge") is being considered. High (low) VIX readings indicate that market participants anticipate high (low) market volatility, respectively. Therefore, the value of VIX is positively correlated with risk aversion.

To construct a density forecast of the exchange rate a Monte Carlo approach is applied. In simple terms, we need to establish (simulate) what is the state of the financial markets on the next day. To this end, we use empirical probabilities of transition between the three aforementioned regimes, and then we randomly choose a daily exchange rate return from the empirical distribution for a given regime. Such steps (first simulating the regime on the next day and then randomly choosing the rate of return) are repeated N times. By doing so we can obtain a simulated distribution of the exchange rate on the next day. Those steps are then reiterated to extend the forecast horizon.

The proposed approach has been examined in a one-month ahead forecasting exercise for 22 emerging market currency rates vs. the US dollar (i.e. USDBRL, USDPLN, etc.). Multiple density forecast evaluation tools suggested proper calibration of the proposed approach, as well as its usefulness for Value at Risk analysis of the majority of the emerging markets' exchange rates. The quality of forecasting performance of the proposed approach was also evaluated against some benchmarks: random walk, threshold autoregressive model and AR(1)-GARCH(1,1) model. The density forecasts produced with our method are superior to random walk forecasts in the case of all 22 analyzed currency pairs, and for 7 exchange rates this advantage is statistically significant. In the case of 19 analyzed currency pairs our method performs better than the threshold autoregressive model, and for 11 exchange rates this forecasting edge is statistically significant. In the case of 15 analyzed currency pairs the proposed approach yields better results than the AR(1)-GARCH(1,1) benchmark, but in none of the cases this difference is statistically significant.

3.4 Pressure from other countries as an important determinant of the exchange rates

In the three articles discussed above, foreign factors affecting the exchange rates of emerging markets were analyzed mainly through the lenses of changes in global risk aversion. The fourth publication discusses the influence of a factor of foreign origin on the exchange rate, but specific to a specific currency – the Chinese Renminbi. The article entitled "The quest for determinants of Chinese exchange rate policy" was published in the journal *Bank & Credit* (Borowski, Czerniak, Jaworski, 2014).

We analyze whether the external factor in the form of a pressure exerted by the US policymakers had an impact on the Chinese exchange rate policy in the 2000-2011 period. During this time the Chinese Renminbi (RMB) exchange rate vs. the US dollar was not free-floating, but was tightly managed by the People's Bank of China (PBoC). Many studies have revealed a significant undervaluation of RMB (Cline, Williamson 2010; Dunaway, Li 2005; Dunaway et al. 2006; Sato et al. 2012; Tyers et al. 2008). As a corollary, some authors advocated faster RMB appreciation so as to limit the current account surplus in China, reduce global imbalances and avoid boom-and-bust policy (Liu, Fan 2010; Goldstein, Lardy 2006; Frankel 2006). One of the most vigorous opponents of PBoC intentionally keeping the RMB undervalued was the US government. In the analyzed period US officials were intensely pressuring China to appreciate its currency. This pressure took the form of speeches and meetings between US officials and Chinese policymakers, including talks during Strategic Economic Dialogue (SED). Moreover, in numerous Reports to Congress on International Economic and Exchange Rate Policies US Treasury criticized Chinese exchange rate policy and suggested that China may be deemed as "currency manipulator" if measures allowing greater appreciation of RMB are not taken.

After China abandoned a decade-long dollar peg in July 2005, the PBoC tightly managed the RMB exchange rate by means of sterilized foreign exchange intervention, at the same time allowing a gradual appreciation of RMB. In this context a following question should be addressed – to what degree RMB changes engineered by PBoC were motivated by the evolution of macroeconomic trends in the Chinese economy, and to what extent they reflected the external pressure exerted by US officials and institutions. To the best knowledge of the authors this issue had not been a subject of empirical assessment before.

We used an ordered logit model to identify the PBoC decision function. The dependent qualitative variable can amount to three different values, depending on whether the RMB rate appreciated, depreciated or remained unchanged in a given month. The potential explanatory variables include indicators regarding domestic economic situation in China (GDP growth rate, inflation, monetary aggregates, trade balance, etc.), as well as regressors reflecting external pressure exerted by US officials and institutions on PBoC to appreciate their currency.

According to our econometric analysis, only three variables have a significant influence on exchange rate policy of PBoC – annual real GDP growth rate, trade balance, and a binary variable "meetings". The last variable is equal to 1 in months when there was a meeting of Chinese and US officials (visits of US Treasury Secretaries Henry Paulson and Timothy Geithner to China, Strategic Economic Dialogue meetings or G20 and G7 summits, and equal to 0 in other months. The other potential explanatory variables (inflation, M0 aggregate and deposit rate) proved to be statistically insignificant.

The econometric analysis described in the article shows that in 2000-2011 period the Chinese exchange rate policy was driven by two factors. First, it was used to protect the export sector and not as an anti-inflationary tool. We found evidence of PBoC showing more tolerance for RMB appreciation against the US dollar when the real economy (trade balance or GDP growth) improved. Second, while managing the RMB exchange rate, the PBoC reacted to pressures from the US urging China to increase the RMB value.

3.5 A renewed importance of domestic factors in shaping the exchange rates of Central and Eastern European currencies

The fifth, and the last in the series, article refers directly to the results of the first publication in this collection (Borowski, Jaworski, 2015), which indicated a decreased importance of local business cycles as a factor shaping the exchange rates of the CEE-4 countries, in favor of a relative increase in the importance of global factors after the outbreak of the global financial crisis. In the latest study, I show that domestic factors have again become relevant to the exchange rates in recent years and I use this fact in constructing forecasts. The article is entitled: "Forecasting Exchange Rates for Central and Eastern European Currencies Using Country-Specific Factors". This work has been accepted for publication in the *Journal of Forecasting* (Jaworski, 2020).

Obstfeld and Rogoff (2000) coined the term "forecasting puzzle" to describe the "exceedingly weak relationship (except, perhaps, in the longer run) between the exchange rate and virtually any macroeconomic aggregates". Bahmani-Oskooee et al. (2015) showed that the relationship between the exchange rate and its fundamentals in the short-run is not very clear, especially in the era of high exchange rate volatility, where the spot exchange rate may be influenced by a number of other possibly unobserved variables. Berg and Mark (2015) referred to these factors as "third-country" effects, or equivalently, spillover effects from the "rest of the world".

In this paper, I attempted to find the relationship between the domestic macroeconomic indicators and the CEE-4 exchange rates (EURPLN, EURCZK, EURHUF and EURRON). My approach is to utilize principal component analysis to separate the global component, which is common for all CEE-4 currencies, from the country-specific local components, and apply independent procedures to forecast those two groups of factors.

The main findings are the following: First, the importance of the global factor indeed increased after the 2008 to 2012 financial crisis, but its role in shaping the returns of CEE currencies declined in recent years.

Second, I managed to capture the connection between the future values of macroeconomic fundamentals and exchange rate returns. Markets' expectations of higher or accelerating inflation and/or GDP growth rate lead to appreciation of the local currency. Such tendencies may be explained through the lenses of monetary policy – expectations for monetary policy tightening, which are conducive to the appreciation of the currency

Third, the aforementioned models were used to forecast the CEE-4 exchange rates. The out-of-sample forecasting exercise suggests that our method is able to beat the random walk in the case of EURHUF and EURRON forecasts in terms of the RMSE in the horizon of 1 to 13 months. For EURCZK and EURPLN, I was able to consistently improve on the random walk in the horizon beyond eight months. In the shorter run, there was no statistical difference between our forecasts and the random walk .

4. Summary

The analysis carried out within the framework of the articles presented above allowed to confirm all five research hypotheses. Modeling and forecasting exchange rates is a substantial and actual topic. From this perspective, the doctoral dissertation, apart from the cognitive character of the results and conclusions, also provides practical contributions. In analytical terms, the proposed novel algorithms for forecasting exchange rates offer added value.

The econometric analysis carried out in the first article indicates that in the case of small open economies, significant, long-lasting, negative and global demand shocks, forcing the use of non-standard monetary policy instruments by central banks of developed countries, may contribute to the weakening of the domestic currency's response to changes in domestic interest rates. Among the global factors, changes in global risk aversion, reflected in a rapid outflow / inflow of portfolio capital from the bond and equity markets, are of key importance in influencing the exchange rate in the CEE-4 countries (Poland, Hungary, Czech Republic and Romania). Thus, the first research hypothesis was confirmed.

The diminishing response of the exchange rate to changes in domestic interest rates signals a weakening of the exchange rate channel in the monetary policy transmission mechanism, thus reducing the effectiveness of its countercyclical properties. The above results indicate that the cost of losing an independent monetary policy after the possible accession of the CEE-4 countries to the euro area may be lower than assessed before the global financial crisis. This should be taken into account in future research on estimating the net benefits of monetary integration of the CEE-4 countries with the euro area. The obtained results are also important for deciding about so-called policy-mix, i.e. a combination of fiscal and monetary policy, in a small open economy in the event of a significant global economic shock.

The issues presented in the article are substantial and especially up-to-date due to the outbreak of the COVID-19 pandemic. For example, the Monetary Policy Council pointed out in 2020 that *"pace of the economic recovery could also be limited by the lack of visible zloty exchange rate adjustment to the global pandemic-driven shock and to the monetary policy easing introduced by National Bank of Poland"*. It can be assumed that the small scale of the PLN depreciation in the period February-June 2020 is the result of a modest (relative to the US and euro area) loosening of the monetary policy in Poland, and of the increased global demand for risky assets due to the gradual lifting of restrictions introduced in connection with COVID-19 and the associated improvement in short-term economic growth prospects in many countries. The conducted research supports such reasoning.

In the second article I showed that changing risk aversion negatively impacts experts' forecasting accuracy, namely it causes distortions in a form of one-directional errors. Using data from 2013-2018 period, I observed that professionals' exchange rate forecasts show a tendency to miss the target in the same direction (overshooting or undershooting vs. the ex post observation) simultaneously in the case of the majority of emerging markets' exchange rates.

I showed, using econometric modeling, that increase of global risk aversion leads to intensification of the mean-reverting property of professionals' forecasts – i.e. the expectation

of a reversal of trends in the currency market. Moreover, the analysts' bias (i.e., systematically too high or too low forecasts compared to their ex-post realization) occurs not only for a single exchange rates but simultaneously for multiple currency pairs. This error is one-directional and has a common origin – it intensifies as the risk aversion increases. Such conclusion confirm the second research hypothesis.

The findings are noteworthy in the context of interrelationship of market sentiment in different countries due to globalization and its impact on distortions in exchange rate expectations. Our results are also vital regarding the properties of professionals' exchange rate forecasts – particularly regarding mean reversion and forecast bias.

In the third article, a novel method to generate density forecasts of emerging markets' exchange rates was proposed. This algorithm aims to establish (simulate) the next-day state of the financial market – elevated risk aversion, low risk aversion or a neutral one. To construct a density forecast of the exchange rate a Monte Carlo approach is applied.

Thorough examination indicated that the proposed algorithm is suitable to generate density forecast for the majority of the 22 analyzed emerging markets' exchange rates. By capturing the influence of changing sentiment in global financial markets I was able to generate density forecasts of exchange rates that are superior to random walk forecasts. This confirms the third research hypothesis.

This paper contributes to the relevant literature in that I propose a new approach to constructing density forecasts of exchange rates. The conducted evaluation of the proposed model indicates that such a tool can be useful for economists, risk managers, econometricians or policy makers focusing on producing density forecasts of foreign exchange rates.

In the first three articles, the external factors influencing the emerging markets' exchange rates were analyzed mainly in the context of changing global risk aversion. In the fourth publication, we also investigate the foreign determinants for one particular currency – the Chinese Renminbi (RMB). The conducted analysis illustrates that in 2000-2011 the Chinese exchange rate policy was driven by two factors. First, the domestic economic situation (represented by trade balance or GDP growth variables). Second, while managing the RMB exchange rate, the People's Bank of China reacted positively to pressures from the US urging China to allow appreciation of the RMB.

To the best knowledge of the authors the analysis of the decision function of the People's Bank of China concerning setting of the RMB exchange rate against the US dollar has not been a subject of empirical assessment before. The findings are interesting in the context of impossible trinity dilemma which assumes that fixed exchange rate is compatible with independent monetary policy pursued under capital controls. This theorem, however, is usually applied for small open economies (with some reservations regarding effectiveness of capital controls). In large open economies, to which China clearly belongs, the exchange rate policy cannot be pursued regardless of its international ramifications.

Although the analysis was conducted using data on the 2000-2011 period, the results are still valid and especially interesting in the context of the ongoing US-China trade war. Due

to a significant weakening of RMB in 2018, the US again started to consider naming China a "currency manipulator". The conclusions presented in the study are therefore useful to analyze the RMB evolution in the coming quarters.

The fifth, and the last, article refers directly to the results of the first publication in this collection (Borowski, Jaworski, 2015), which indicated a decreased importance of local business cycles as a factor shaping the exchange rates of the CEE-4 countries, in favor of a relative increase in the global factors importance after the outbreak of the global financial crisis. This research showed that the importance of the global factors indeed increased after the financial crisis of 2008–2012, but their role in shaping the returns on CEE-4 currencies has decreased in recent years. Such conclusion is crucial for forecasting these exchange rates.

Moreover, in the article I showed that the local component of CEE-4 exchange rates can be explained via the framework of linear regression by future values of macroeconomic fundamentals – CPI inflation and GDP growth rate. Then, I presented a thorough evaluation of the forecasting performance of the novel approach, focusing on modelling the local component. The out-of-sample forecasting exercise indicates that our forecasting approach yields superior results compared to the random walk in the case of the CEE currencies of Poland, Czech Republic, Hungary, and Romania. The model presented in this study is therefore a valid contribution to the body of literature on exchange rate forecasting. The conclusions from this study allow to confirm the fifth research hypothesis.

5. The collection of thematically consistent articles constituting the doctoral dissertation

Articles published or accepted for publication in scientific journals:

1. Borowski, J., Jaworski, K. (2015). Globalny kryzys finansowy a koszty utraty autonomii monetarnej w wybranych krajach Europy Środkowo-Wschodniej (Global financial crisis and costs of losing the independent monetary policy in the selected Central and Eastern European countries). *Ekonomista*, (3), 319-334.

My contribution to this article is estimated at 50%. It consists of proposal and estimation of econometric models, as well as interpretation and discussion of the results in the manuscript.

2. Jaworski, K. (2018). Wpływ zmian globalnej awersji do ryzyka na eksperckie prognozy kursów walutowych w kontekście rosnącej internacjonalizacji rynków finansowych (Impact of changing risk aversion on professionals' exchange rate forecasts in the context of growing internationalization of financial markets). *Studia Ekonomiczne, Zeszyty Naukowe Uniwersytetu Ekonomicznego w Katowicach*, (372), 149-160.

3. Jaworski, K. (2019). Sentiment-induced regime switching in density forecasts of emerging markets' exchange rates. Calibrated simulation trumps estimated autoregression. *Bank i Kredyt*, (1), 83-106.

4. Borowski, J., Czerniak, A., Jaworski, K. (2014). The quest for determinants of Chinese exchange rate policy. *Bank i Kredyt*, 45(5), 407-432.

My contribution to this article is estimated at 40%. It consists of constructing the variables reflecting pressure of US government on China, estimation of econometric models, as well as interpretation and discussion of the results in the manuscript.

5. Jaworski K. (2020). Forecasting Exchange Rates for Central and Eastern European Currencies Using Country-Specific Factors. *Journal of Forecasting*, accepted for publication, doi:10.1002/for.2749.

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7. Appendix – Research and academic activity

EDUCATION

1. Ph.D. Studies, Warsaw School of Economics, 2015-2019
   Economic Analysis of Financial Markets
   Supervisor: Associate Professor Ewa M. Syczewska, PhD

2. M.A. in Economics, Warsaw School of Economics, 2011-2013
   Major: Quantitative Methods in Economics and Information Systems
   Two specializations: Statistical analysis and data mining; and Econometrics.
   Thesis title: Business cycles modelling. Case of the USA.
   Supervisor: Associate Professor Ewa M. Syczewska, PhD

3. B.A. in Economics, Warsaw School of Economics, 2008-2011
   Major: Quantitative Methods in Economics and Information Systems
   Two specializations: Econometrics and Methods of Decision Analysis
   Thesis title: Modelling and forecasting demand for electricity in Poland.
   Supervisor: Associate Professor Ewa M. Syczewska, PhD

PUBLICATIONS IN SCIENTIFIC JOURNALS

1. Jaworski K. (2020). Forecasting Exchange Rates for Central and Eastern European Currencies Using Country-Specific Factors. Journal of Forecasting, accepted for publication, doi: 10.1002/for.2749.
2. Borowski J., Jaworski K., Błaszyński P. (2020). Wpływ imigracji zarobkowej na dynamikę płac w Czechach, Polsce, Rumunii i na Węgrzech. [in:] Nauki społeczne jako przedmiot badań naukowych – ujęcie interdyscyplinarne. Śliwa M., Maciąg M. (ed.), Wydawnictwo Naukowe Tygiel sp. z o.o., Lublin.
3. Jaworski, K. (2019). Sentiment-induced regime switching in density forecasts of emerging markets' exchange rates. Calibrated simulation trumps estimated autoregression. Bank i Kredyt, (1), 83-106.
4. Jaworski, K. (2018). Wpływ zmian globalnej awersji do ryzyka na eksperckie prognozy kursów walutowych w kontekście rosnącej internacjonalizacji rynków finansowych. Studia Ekonomiczne, Uniwersytet Ekonomiczny w Katowicach, (372), 149-160.
5. Borowski, J., Jaworski, K., Olipra, J. (2019). Economic, institutional, and socio-cultural determinants of consumer credit in the context of monetary integration. International Finance, 22(1), 86-102.
6. Jaworski K. (2018). "Density Forecasts of Emerging Markets' Exchange Rates Using Monte Carlo Simulation with Regime Switching". [in:] Jajuga K., Locarek-Junge H., Orlowski L. (eds) Contemporary Trends and Challenges in Finance. Springer Proceedings in Business and Economics. Springer, Cham.
7. Borowski J., Jaworski K., Olipra J. (2017). Economic, institutional and socio-cultural determinants of consumer credit in the context of monetary integration, NBP Working Paper No. 254.
8. Borowski, J., Jaworski, K., Tymoczko, D. (2016). Wpływ podatku bankowego w Polsce na kredyt dla sektora niefinansowego. Studia Ekonomiczne, Uniwersytet Ekonomiczny w Katowicach, 6(287), 7-21.

9. Jaworski, K. (2016). Modelowanie cykli gospodarczych na podstawie ankietowych badań koniunktury: analiza na przykładzie USA. Bank i Kredyt, (1), 33-59.
10. Borowski, J., Jaworski, K. (2015). Globalny kryzys finansowy a koszty utraty autonomii monetarnej w wybranych krajach Europy Środkowo-Wschodniej. Ekonomista, (3), 319-334.
11. Borowski, J., Czerniak, A., & Jaworski, K. (2014). The quest for determinants of Chinese exchange rate policy. Bank i Kredyt, 45(5), 407-432.
12. Borowski J., Jaworski, K. (2014). "Globalny kryzys finansowy a synchronizacja cykli koniunktury w krajach Europy Środkowo-Wschodniej", [in:] "Zjawiska i procesy w gospodarce światowej i jej podsystemach", [Eds] Sporek T., Talar S., Wydawnictwo Uniwersytetu Ekonomicznego w Katowicach, Katowice

CONFERENCES, WORKSHOPS AND SEMINARS

1. Second Vienna Workshop on Economic Forecasting (2020), host: Institute for Advanced Studies (IHS), paper: "Nowcasting daily food inflation during COVID-19 pandemic. Case of Poland".
2. III Conference "Ekonomicze, kulturowe i społeczne wymiary migracji" [„Economic, cultural and social aspects of migrations"] (2020), host: Foundation for development of science and development TYGIEL, paper: Wpływ imigracji zarobkowej na dynamikę płac w Czechach, Polsce, Rumunii i na Węgrzech", co-author J. Borowski
3. NBP Workshop on Forecasting (2018), host: National Bank of Poland, paper: "Forecasting emerging markets' exchange rates by distinguishing the impact of local and global components".
4. XVII Conference: „Procesy internacjonalizacji w gospodarce światowej" [„Internationalization processes in global economy"] (2018), University of Economics in Katowice, paper: „Wpływ zmian globalnej awersji do ryzyka na eksperckie prognozy kursów walutowych w kontekście rosnącej internacjonalizacji rynków finansowych".
5. NBP Workshop on Forecasting (2017), host: National Bank of Poland, paper: "Density forecasts of emerging markets' exchange rates using Monte Carlo simulation with regime switching".
6. Conference: "Econometric Research in Finance Workshop" (2017), host: Warsaw School of Economics, paper: "Density forecasts of emerging markets' exchange rates using Monte Carlo simulation with regime switching".
7. Conference: "Wrocław Conference in Finance" (2017), host: Wrocław University of Economics, paper: "Density forecasts of emerging markets' exchange rates using Monte Carlo simulation with regime switching".
8. Seminar regarding the "Economic, institutional and socio-cultural determinants of consumer credit in the context of monetary integration" research project. (2016), National Bank of Poland, co-authors: J. Borowski, J. Olipra
9. XII conference in the cycle "Procesy internacjonalizacji w gospodarce światowej" [„Internationalization processes in global economy"] (2013), host: University of Economics in Katowice, paper: „Globalny kryzys finansowy a synchronizacja cykli koniunktury w krajach Europy Środkowo-Wschodniej".
10. Conference „Nowe procesy w gospodarce światowej. Wnioski dla Polski". [„New processes in global economy. Conclusions for Poland"] (2013), host: Institute of International Economics, Warsaw School of Economics, paper: „Globalny kryzys

finansowy a koszty utraty autonomii monetarnej w krajach Europy Środkowo-Wschodniej", co-author: J. Borowski

GRANTS AND RESEARCH PROJECTS

1. Principal investigator: „Utilisation of online data for the purpose of measuring and nowcasting food inflation, and analysis of price shocks transmission and price stickiness. Case of Poland". Research project financed by the National Science Centre (2017-2021).
2. Principal investigator: „Comparison of the influence of local and global factors on the emerging markets' exchange rates". Research project financed from the funds for Studies of Young Researchers of the Collegium of Economic Analysis (2018).
3. „Economic, institutional and socio-cultural determinants of consumer credit in the context of monetary integration", with J. Borowski and J. Olipra. Research project financed by the National Bank of Poland (2014-2016) – VI competition for research projects.
4. „Impact of the planned increase of minimum wage in 2020-2024 period on wages and employment in Poland" with J. Borowski. Research project financed from the funds for statutory research of the Collegium of World Economy (2020).
5. „Impact of economic migration on wage growth in Czech republic, Poland, Romania and Hungary", with J. Borowski. Research project financed from the funds for statutory research of the Collegium of World Economy (2019).
6. „Impact of changing risk aversion on professionals' exchange rate forecasts in the context of growing internationalization of financial markets". Research project financed from the funds for statutory research of the Collegium of World Economy (2018).

REVIEWS

1. International Journal of Finance and Economics
2. Computational Economics

TEACHING EXPERIENCE

Since February 2018 I work as an Assistant at the Department of Economics II at Collegium of World Economy at the Warsaw School of Economics. I teach seminars on Microeconomics I and Macroeconomics I at the Bachelor studies (both in Polish and in English). The seminars correspond to lectures of Małgorzata Znoykowicz-Wierzbicka, PhD and Piotr Maszczyk, PhD.

AWARDS AND DISTINCTIONS

1. Rector's certificate of recognition for publication in a scientific journal indexed in the Journal Citation Reports database.
2. Scholarship for best PhD students and scholarship for exceptional master and bachelor students
3. Winner of the 4th edition of the competition "If it were up to me..." (2015) - competition for the best research paper regarding proposed changes in public policy, organized by the National Bank of Poland
4. Winner of the „Polish Award of Intelligent Development 2020" in category "Scientist of the future" for the innovative nature of the research project "Utilisation of online data for

the purpose of measuring and nowcasting food inflation, and analysis of price shocks transmission and price stickiness. Case of Poland"

5. Top positions in various competitions for the most accurate forecasts of macroeconomic indicators and exchange rates organized by Parkiet and Rzeczpospolita dailies, Thomson Reuters and Bloomberg press agencies

Krystian Jaworski