ORIGINAL PAPER

DOI: 10.26794/2587-5671-2019-23-4-117-128
UDC 336.74,339.743(045)
JEL F31, E52

Estimation of Impact of Quantitative Easing Policy on EUR/USD using Behavioral Equilibrium Exchange Rate Model

A.A. Vinogradov
Lomonosov Moscow State University, Moscow, Russia;
Sberbank CIB, Moscow, Russia
https://orcid.org/0000-0003-0025-4345

ABSTRACT

The article examines the impact of the policy of the USA quantitative easing and the euro area on the nominal EUR/USD exchange rate. After the economic crisis of 2008–2009, the policy of quantitative easing gained popularity among the world's largest economies. The largest programs were implemented by the US Federal Reserve (US Federal Reserve System) and the European Central Bank (ECB). However, the impact of the actual purchase volume of securities on the EUR/USD exchange rate within these policies has been little studied in modern literature. The author collected the data from 1999 to 2018 on the exchange rate, macroeconomic and market indicators, and calculated the monthly actual purchase volumes of securities under the asset purchase program of the United States and the euro area. The behavioral equilibrium exchange rate model was used. The linear model specification and the error correction model identified no significant impact of the ECB quantitative easing policy expressed in the actual purchase volume of securities. However, for some specifications, it has been proven that the increase in purchases of securities by the US Federal Reserve leads to a weakening of the dollar against the euro. The cointegration test revealed a long-term dependence of the EUR/USD exchange rate on the accumulated volumes of acquired assets. Thus, an increase in the purchase volume of securities led to a weakening of the dollar against the euro. The insignificant impact of the European Central Bank quantitative easing policy could have been caused by market expectations formed prior to the actual purchase of ECB securities in the market.

Keywords: macroeconomics; finance; economic policy; non-standard monetary policy; quantitative easing; euro area; European Central Bank (ECB); Federal Reserve System; exchange rate; EUR/USD; VECM; BEER

For citation: Vinogradov A.A. Estimation of impact of quantitative easing policy on EUR/USD using behavioral equilibrium exchange rate model. *Finance: Theory and Practice.* 2019;23(4):117-128. DOI: 10.26794/2587-5671-2019-23-4-117-128

INTRODUCTION

Studying exchange rate dynamics is an important task for economic policy and financial markets. For example, the government plans export revenues and companies make revenue forecasts based on exchange rate forecasts. The EUR/USD exchange rate is one of the most popular and often traded world currency pairs, therefore it is of interest for this study.

In present-day conditions, after the 2008 economic crisis, the United States and the euro area countries resorted to unconventional monetary policy, in particular, policies of quantitative easing and zero interest rates. In 2008–2014, The United States conducted the largest-scale asset purchase program as part of quantitative easing policy, and in 2015–2018, the European Central Bank substantially expanded its asset purchase program. Such a policy was expected to strengthen the transmission mechanism of the conventional monetary policy which would help accelerate economic growth and achieve the target inflation rate. The impact on exchange the rate is less predictable.

This paper examines the impact of the quantitative easing policies on the nominal EUR/USD exchange rate.

In 2015–2018, the quantitative easing policy of the euro area countries was due to a decrease in long-term interest rates on bonds as shown in the work by M. Ferrari, J. Kearns [1]. All things equal, this can reduce the flow of investment into the country and weaken the exchange rate.

Among the factors affecting the exchange rate, interest rate differential, risk premium, public debt and terms of trade were identified in the literature [2]. In this study, most of the factors are used as control variables, and the target variable is the actual volume of purchase of securities under the quantitative easing program in the US and the euro area.

The aim of the study is to estimate the impact of the ECB and the FRS quantitative easing policies on the nominal EUR/USD exchange rate. Unlike previous works on similar topics, the impact of the quantitative easing policies in these two countries is estimated simultaneously. To estimate the impact on the EUR/USD exchange rate, the author used the volumes of purchased securities obtained from the ECB and the FRS data. Besides, the work uses two behavioral equilibrium exchange rate (BEER) models, a linear model and an error correction model with several specifications. The following factors are used as controlling factors: difference between short-term and long-term interest rates, oil price, spread between growth rates of industrial production, difference between the inflation rates, growth rate of money supply, and volatility index VIX.

As a result, this work did not reveal a short-term significant effect of the ECB quantitative easing policy on the on the EUR/USD exchange rate, however, the impact of the US quantitative easing policy is significant for some specifications. The cointegration analysis showed a long-term relationship between the euro and the variables reflecting the volume of purchases of securities. The structure of the article comprises the review of the literature on exchange rate models, the description of the quantitative easing policies in the USA and the euro area, the description of the model used by the author to estimate the impact of the quantitative easing policies, the results of the model evaluation with discussion and the conclusions.

LITERATURE REVIEW

In recent decades, presented in the foundational work by M. Ferrari and J. Kearns [1], behavioral equilibrium exchange rate models have begun to gain popularity. These models explain the exchange rate dynamics in an abridged (non-structural) form allowing to evaluate the model just by econometric methods. The paper [1] also presents a linear model for the exchange rate dynamics.

The frequency of the data largely determines the opportunity to use various observable factors affecting the exchange rate. In the short term (on daily and intraday data), such factors as interest rates, volatility indices and unemployment rates are highlighted [3], however, long-term variables such as money supply and industrial output are generally unavailable.

The studies of the impact of the quantitative easing policy on the daily euro rate [4] revealed

weakening of the euro against the dollar one and two days after the quantitative easing policy was announced. In work [3], intraday data showed weakening of the exchange rate in the country (several exchange rates against the US dollar were used) after the news about stimulating unconventional monetary policy. The overnight indexed swap (OIS) change was used as a variable reflecting the policy change.

Volatility clustering is also observed in the daily rate data [5] which can be described by the GARCH models.

Monthly data allow to identify more long-term trends in the exchange rate dynamics used for forecasting and the factors affecting it. However, one of the fundamental articles on forecasting the exchange rate [6] revealed the predominant predictive power of the random walk model for the current value of the exchange rate over several models that use fundamental factors to forecast the exchange rate.

However, more current works propose many fundamental factors that together can explain the valid part of the exchange rate change. Work [7] already demonstrates an improvement in the predictive power of a model based on the fundamental factors compared with a random walk.

One of the most popular factors highlighted in the literature is uncovered interest rate parity. Uncovered interest rate parity determines the expected change in the exchange rate depending on the spread between the interest rates in the economies.

$$\Delta s^e = \frac{1+i_d}{1+i_f} - 1$$, where Δs — is the expected change in the exchange rate (in units of foreign currency); i_d^e — is the short-term interest rate in one country; i_f^e — is the short-term interest rate in another country.

However, uncovered interest rate parity often does not work in the short term, for example, due to capital flows. Capital from other countries is sent to a country with a higher interest rate (carry trade operations). As a result, the country's currency may strengthen. The effect of uncovered interest rate parity is usually reflected in the spread between short-term interest rates of the countries.

Work [8] estimated the effects of the quantitative easing measures by the ECB and the Federal Reserve on the EUR/USD exchange rate by means of the model based on covered interest rate parity. The policy shocks were identified based on a change in the balance sheet of assets and liabilities of the central bank.

The interest rate parity itself is not sufficient to explain the exchange rate dynamics, since the data do not show the effect of parity under rational expectations. The forward value of the exchange rate is a poor indicator to change the value of the spot exchange rate. The so-called "uncovered interest parity puzzle" means the deviation of the exchange rate dynamics from the results of uncovered interest parity. In work [9] this deviation is explained by risk premium.

Another popular factor determining the exchange rate dynamics is purchasing power parity. It suggests the effect of the spread in inflation on the exchange rate.

$$\Delta s^e = \frac{1+\pi_d^e}{1+\pi_f^e} - 1$$, where Δs — is the expected change in the exchange rate (in units of foreign currency); π_d^e — is the expected inflation in one country; π_f^e — is the expected inflation in another country. This factor, as well as uncovered interest rate parity, is insufficient to explain the exchange rate dynamics, but the inflation rate differential is often used as one of the factors in BEER models.

Among the early models explaining the nominal exchange rate dynamics by fundamental factors, several basic types are used. The monetary model [10–12] assumes the dependence of the exchange rate on the relative demand for money in the two countries. In sticky-price monetary models (as opposed to flexible price monetary models), only long-term fulfillment of purchasing power parity is assumed. When using this model in empirical work, several fundamental factors affecting the exchange rate are identified. Among

them: monetary aggregates, a gap in aggregate output, interest rates, trade balance, inflation and terms of trade.

The portfolio balance model [13] introduces the premise of the imperfect asset substitutability of the two countries. In this model, the exchange rate, in addition to the spread in interest rates, is determined by government securities in national currency.

Various econometric models were used to estimate the impact of the quantitative easing policy. J. Boeckx, M. Dossche, G. Peersman [14] proposed to estimate the impact of asset purchases on the euro. The Deutsche Bundesbank report for January 2017 on the purchase of Eurosystem bonds and the euro exchange rate[1] used the non-structural BVAR model with variables:

- nominal effective exchange rate of the euro;
- ECB assets intended for the implementation of monetary policy;
- ECB liquidity used for monetary policy;
- ECB main refinancing rate;
- harmonised index of consumer prices for the countries of the euro area;
- industrial production index;
- Euro Stoxx 50 stock market index volatility.

As a result of the model evaluation in work [14], a decrease in the exchange rate at an increase in the assets of the ECB was revealed.

In other works, structural models reflecting the influence of the quantitative easing policy on the rate were also built. The study by G. Adler, R. Lama, and J. Medina [15] built a dynamic stochastic general equilibrium model for the two countries, considering the impact of the quantitative easing policies on the exchange rate.

Using the panel quarterly data, C. Engel, N. Mark, K. West [16] offered and built a factor model that used the information embedded in the exchange rates to forecast. The resulting model presented some forecasting results that exceeded a basic random walk model.

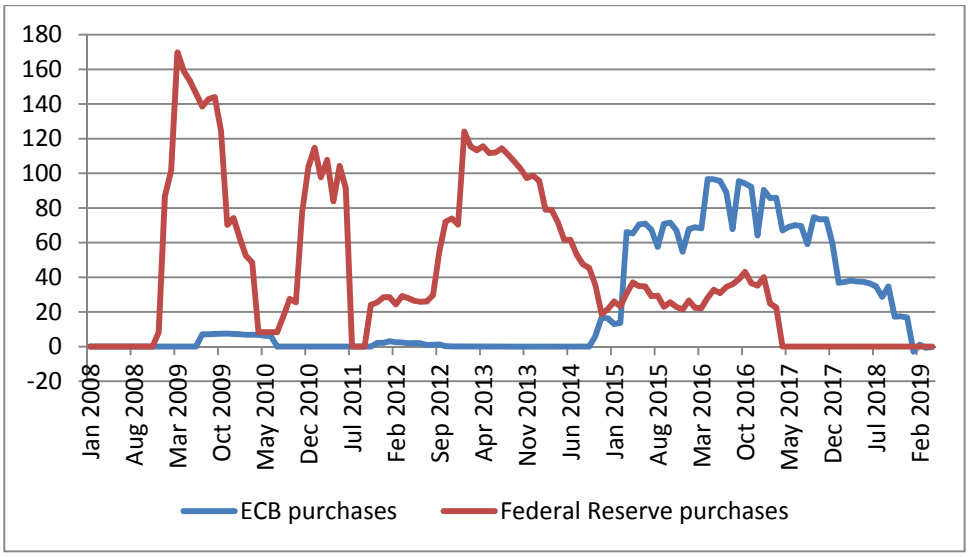
In general, most of the works converge on the influence of unconventional measures of monetary policy close to the effect of conventional measures. Quantitative easing policy reduces long-term interest rates in the economy, which leads to a decrease in investment attractiveness and a weakening currency.

QUANTITATIVE EASING POLICY IN THE US AND EURO AREA COUNTRIES

Before the global economic crisis, unconventional monetary policy, such as policies of zero interest rates and quantitative easing, was rarely used, and the volume of purchases of securities was relatively small. After the 2008–2009 global economic crisis, economic growth and inflation were steadily slowing in the world's leading economies: the US and the euro area. The US annual price growth was negative, and the GDP was declining. Central banks used several unconventional measures of monetary policy to stimulate the economy since conventional measures had exhausted themselves: interest rates reached zero [17]. Those measures included the quantitative easing policy which consisted in purchasing securities from the private and public sectors by the central bank and expanding the balance of the central bank according to the classification of unconventional monetary policy [18]. As a result, the US Federal Reserve expanded its asset purchase program to stimulate the economy and maintain inflation. In 2008–2014, the FRS bought more than $ 5 trillion in the open securities market. The three-stage program mainly included the purchase of treasury bonds, bonds of mortgage agencies Fannie Mae and Freddie Mac and mortgage-based securities (MBS) of these agencies.

The first stage of the program began at the end of 2008 and included the purchase of MBS in the amount of $ 1.25 trillion and the purchase of agency bonds in the amount of $ 175 billion (*Fig.*). At the second stage of the program (November 2010 — June 2011), the US long-term government securities were purchased for $ 600 billion. The operational twist between the second and third stage (September 2011 — December 2012) included the exchange of short-term bonds for long-term bonds in the amount of about $ 600 billion.

[1] Deutsche Bundesbank, The Eurosystem's bond purchases and the exchange rate of the euro, Monthly Report, January, 2017. URL: https://www.bundesbank.de/resource/blob/707604/ad5d6a4c1a430a1bfee21a378572f87a/mL/2017–01-anleihek-aeufe-eurosystem-data.pdf (accessed on 18.07.2019).



Volume of securities purchased under asset purchase programs, billion dollars

Note: the volume of asset purchased by ECB converted from EUR into USD at the exchange rate at the time of the purchase

Source: ECB, FRED, calculated by the author.

At the third stage (September 2012 — October 2014), long-term government bonds were bought at a rate of about $ 45 billion per month and MBS about $ 40 billion per month.

After the 2008 crisis, the ECB started its quantitative easing policy in relatively small volumes. In 2015–2018, in order to strengthen the transmission mechanism of conventional monetary policy and to combat low inflation and GDP growth after the crisis, the ECB substantially expanded its asset purchase program consisting of four subprograms: corporate sector purchase program, public sector purchase program, covered bond purchase program, asset-backed securities purchase program. The largest volume of purchases was accounted for by the public sector purchase program. Purchases of securities under the ECB program took place simultaneously with the policy of zero interest rates in the euro area.

Unlike the US asset purchase program, this program was ongoing. Another feature of this program is the differences between countries whose securities were purchased. Purchases were made in accordance with the "capital key" which determines the volume of purchases depending on the country's GDP. Thus, the largest volume of purchases by country belonged to countries with a high debt burden (Italy), and with a low one (Germany, France). The total volume of purchases of securities under the ECB quantitative easing program amounted to about $ 3.1 trillion in equivalent at the exchange rate at the time of purchase.

Quantitative easing policy primarily affects assets purchased. The works by A. Vissing-Jorgensen, A. Krishnamurthy and R. Motto, C. Altavilla, G. Carboni, [4, 19] demonstrated a decrease in the yields of long-term bonds of the USA and the euro area countries as a result of the policy based on changes in market expectations after the central banks announced unconventional monetary policy measures. The authors explain the mechanism for reducing rates by several channels (signaling channel, default risk channel, portfolio rebalancing channel, and others), via which the announcements of the quantitative easing policy affect long-term government bond rates.

In general, the quantitative easing policy is an important part of monetary and general economic policies of the United States and the euro area countries, so they can play an important role in shaping the EUR/USD exchange rate and other local and global macroeconomic indicators.

EXCHANGE RATE MODEL

This article analyzes monthly data to evaluate the exchange rate model. The base specification

of the BEER model uses the linear model of the following form:

$$y_t = c + \beta X_t + \varepsilon_t,$$

where y_t — is the dependent variable; X_t — is a set of explanatory variables, ε_t — are random shocks; β — is the coefficient vector.

To evaluate the model, monthly data from 1999 to 2018 are used from FRED, the ECB database, S&P Dow Jones Indices and EIA. The average monthly change in the EUR/USD exchange rate is taken as the explanatory variable. The following variables are used as explanatory variables:

- three-month interest rates in the interbank market for the USA and the euro area countries which reflect the influence of the inflow of carry trades according to uncovered interest rate parity;
- ten-year government bond yields of the USA and the euro area countries (yield index, aggregated by country);
- M2 money aggregates for the USA and the euro area countries (seasonally adjusted);
- indices of industrial production (manufacturing) for the USA and countries of the euro area (seasonally smoothed) which reflect economic activity;
- Brent oil price (FOB) in the European market which partially reflects the terms of trade;
- spread in the inflation rate expected by the market between the US and the euro area, reflecting the change in the exchange rate as a result of the effect of the disparity in inflation (purchasing power parity);
- global volatility index VIX based on the option for the US stock index S&P 500 which reflects the risk premium;
- volumes of asset purchases by the ECB and the FRS according to the quantitative easing policy (target variable).

Volumes of purchases of securities in terms of asset purchases in the US and the euro area were calculated based on the ECB and the FRS data.

Market expectations are used as expected inflation. They are calculated from inflation-indexed bonds and straight bonds by formula

$$\pi^e = \frac{1 + y_{IPS}}{1 + y} - 1,$$

where π^e — is the market expected inflation; y_{IPS} — are yields on inflation-indexed government bonds; y — are government bond yields.

The stationarity of the variables in the model was verified by the Dickey-Fuller test.

The vector error correction model (VECM) is used as an extension of the model. The model allows consider the long-term dependence of the exchange rate on the fundamental variables, such as the oil price or the disparity (ratio) between the price level in the USA and the euro area. The specification for a short-term variable (exchange rate change) is similar to the base specification.

The VECM model is as follows:

$$\Delta X_t = C + \Lambda X_{t-1} + \beta_1 \Delta X_{t-1} + \varepsilon_t,$$

where ΔX_t — is the vector of the differences of the studied variables; X_t — is the vector of explanatory variables; Λ — is the coefficient matrix of cointegration vectors; β_1 — is the matrix of lag coefficients of the differences of the studied variables.

To identify cointegration between the variables the Engle-Granger and Johansen tests with one lag for the variables were used before estimation the model. Next, the VECM model based on cointegrating variables was estimated.

RESULTS

The estimation results of the base model demonstrated a diverse effect of the variables depending on their inclusion and transformation. *Table 1* shows the estimation results of three specifications of the basic model with the largest number of regressors and various transformations of the volume of purchases of securities under the quantitative easing program. The variables in the table and their corresponding names are presented in the appendix. The shortest series of expected inflation limited the sample from 2009. Depending on the specification, the differences of the logarithms of the oil price and the spread of money supply growth between the euro area and the United States turned out to be stably significant variables for the differences of the logarithms of the EUR/USD exchange rate (the dependent variable in the model). In most model

Table 1

Basic models of the USD/EUR exchange rate log-differences

	(1)		(2)		(3)	
Constant	1.012	***	1.358	***	1.279	***
	(0.373)		(0.414)		(0.366)	
infl_spr	−0.015		−0.005		−0.003	
	(0.017)		(0.016)		(0.016)	
st_int_spr	−0.007		−0.005		−0.004	
	(0.005)		(0.005)		(0.004)	
lt_int_spr	0.004		0.000		0.002	
	(0.007)		(0.007)		(0.006)	
M2_spr	−1.002	***	−1.238	***	−1.270	***
	(0.379)		(0.382)		(0.370)	
IP_spread	0.111		0.084		0.064	
	(0.193)		(0.188)		(0.197)	
VIX	−0.000		−0.001	*	−0.001	*
	(0.001)		(0.000)		(0.000)	
ld_EuropeBrentSpotPriceFOB	0.073	***	0.057	***	0.055	***
	(0.019)		(0.021)		(0.019)	
l_ECB_purch	−0.001		–		–	
	(0.002)					
l_US_purch	0.002		–		–	
	(0.002)					
l_cumul_ECB_purch	–		−0.000		–	
			(0.003)			
l_cumul_FED_purch	–		−0.013		–	
			(0.012)			
d_l_cumul_ECB_purch	–		–		0.001	
					(0.004)	
d_l_cumul_FED_purch	–		–		0.133	***
					(0.046)	
Adjusted R-squared	0.087		0.100		0.129	
Time period	04.2009–12.2018		04.2009–01.2019		04.2009–01.2019	
P-value (F)	0.000		0.000		0.000	

Note: * – variable is significant at 10%-significance level.

** – variable is significant at 5%-significance level.

*** – variable is significant at 1%-significance level.

Source: calculated by the author.

Table 2

Johansen test results

Rank of cointegration matrix	Trace statistics	Maximum eigenvalue statistics
0	144.87	103.40
	(0.000)	(0.000)
1	41.470	28.018
	(0.175)	(0.041)
2	13.452	8.420
	(0.869)	(0.870)
3	5.032	2.855
	(0.804)	(0.946)

Note: the p-values of the test statistics are showed in parentheses.

Source: calculated by the author.

specifications, the quantitative easing policy variables turned out to be insignificant. The only variable that reflects the US quantitative easing policy in the specification in the third column of *Table 1* turned out to be significant. The positive effect of the stimulating quantitative easing policy of the FRS on the EUR/USD exchange rate (weakening of the dollar against the euro as a result of increased purchases by the FRS) was revealed, which generally corresponds to the results of the other studies. This can be explained by the fact that long-term rates in the US economy are falling making investment in it less attractive. The dollar in this case may weaken. The impact of the ECB's quantitative easing policy turned out to be insignificant.

For the cointegration vector of the EUR/USD exchange rate, the Brent oil price variables, the disparity between the price level in the USA and the euro area and the logarithm of the accumulated volume of purchases of securities were chosen, since they can reveal a long-term dependence of the EUR/USD exchange rate. Before the Johansen test was conducted, the variables had been tested for stationarity by the Dickey-Fuller test. All of the above variables turned out to be non-stationary in levels, but stationary in disparity, which allows to continue analysing cointegration between the variables.

The Engle-Granger test with a constant and without a constant with a lag selected by the Akaike criterion did not reveal cointegration between the EUR/USD exchange rate and other variables.

Nevertheless, the Johansen test with an unlimited constant and one lag revealed a cointegrating vector: the equation of the euro exchange rate with oil prices, the purchasing power disparity (the ratio between the level of consumer prices) and the accumulated volumes of purchases of securities according to the quantitative easing policy (the hypothesis of the absence of cointegrating vectors was rejected for trace statistics and the maximum eigenvalue based on a p-value of less than 1%). The test results are shown in *Table 2*.

The Johansen test results enable the VECM use to identify the long-term relationship between cointegrated variables and the short-term relationship between stationary variables. The VECM model evaluation results are presented in *Table 3*. The first specification provides an equation for a cointegrating vector. The equation indicates that in the long term, the EUR/USD exchange rate depends on the oil price, the price disparity between the US and the euro area and the volume of purchases of securities according to the quantitative easing policy.

The second specification provides an equation for the short-term dependence of the change in the EUR/USD exchange rate on the changes in Brent oil prices, the short-term rates differential, the long-term rates differential, the volatility index VIX, the money supply differential, the disparity changes, the spread between industrial production growth rates, and the changes in purchases of securities according to the quantitative easing policy and the correction term. In the VECM model, the correction

Table 3

Results of the estimation of the VECM model for the USD/EUR exchange rate

	(1)		(2)	
	l_EURUSD		d_l_EURUSD	
l_EuropeBrentSpotFOB	−0.089	константа	0.012	**
	(0.119)		(0.005)	
l_disparity	−3.299	d_l_cumul_ECB_purch	0.004	
	(3.726)		(0.010)	
l_cumul_ECB_purch	0.004	d_l_cumul_FED_purch	0.018	**
	(0.042)		(0.007)	
l_cumul_FED_purch	0.019	ld_EuropeBrentSpotPriceFOB	0.049	***
	(0.028)		(0.016)	
		d_l_disparity	0.516	
			(0.322)	
		VIX	−0.001	***
			(0.000)	
		st_int_spr	0.003	
			(0.002)	
		lt_int_spr	0.004	
			(0.003)	
		IP_spread	−0.075	
			(0.138)	
		EC 1	−0.052	***
			(0.015)	
Time period			02.1999–01.2019	
Adjusted R–squared			0.098	

Note: * — variable is significant at 10%–significance level

** — variable is significant at 5%–significance level

*** — variable is significant at 1%–significance level

Source: calculated by the author.

coefficient turned out to be significant at 1% level. This dependence indicates the negative influence of the adjusting component in the model bringing the euro closer to the long-term value, which corresponds to the theoretical conclusions. Among the control variables, the oil prices and the index VIX were significant at 1% level. The equations of the vector model for the remaining variables are not of interest for this work.

The insignificant impact of the volume of purchase of securities in the framework of the ECB quantitative easing policy can be explained by several factors. First, volume of purchases of bonds may be insufficient to significantly affect the demand for the euro. Second, the cross-country differences in the fundamental macroeconomic indicators for the euro area could reduce the impact of the quantitative easing policies on the exchange rate. For example, lower volumes of purchases of securities by Italy, the country with a relatively high debt level, compared with a large volume of purchases of securities by Germany, with a relatively low debt level. Finally, the actual purchases could be less significant than the expectations regarding the quantitative easing policy. Since the quantitative easing policy in the euro area implied a predetermined volume of purchases of securities, the market could have considered these volumes before the actual purchases. The US quantitative easing policy was less certain about the actual volume of purchases that could have given greater importance to the actual purchases of securities.

CONCLUSIONS

The purpose of this study was to estimate the impact of the quantitative easing policies on the EUR/USD exchange rate. The quantitative easing policy was applied after the economic crisis to achieve the target inflation rate and to stimulate economic activity in the USA and in the euro area. The differences between the approaches to the policy implementation were both in the structure of the purchased securities and in the volume of purchases. The volume of purchases of securities in the United States was greater, and a significant share in their structure was held by mortgage-based securities. The feature of this work is that the impact of the quantitative easing policy in the USA and the euro area were estimated simultaneously.

To identify the effect of the quantitative easing policy, two BEER models were used on monthly data: the basic linear model and the error correction model (ECM). The study found no evidence of a significant impact of the ECB purchases according to the quantitative easing policy. However, in some specifications, the FRS quantitative easing policy was significant. According to the estimated linear and VECM models, the purchase of the US Federal Reserve securities led to weakening the dollar against the euro, which is consistent with the theory. As a result of the quantitative easing policy, the long-term rates in the economy are declining, making the US investments less attractive, and the dollar is weakening due to the increased capital outflows. The Johansen test revealed a long-term dependence of the EUR/USD exchange rate, oil prices, price level disparity on the volume of purchases under the quantitative easing program in the US and the euro area.

The FRS quantitative easing policy was more longlasting and extensive, therefore its effect could be more pronounced than that of the ECB's. The effect of the ECB quantitative easing policy could be insignificant due to the small volume of purchases relative to the market or the effect could be blurred due to the difference in fundamental indicators for countries in the euro area. Besides, the expectation effect of the quantitative easing policy for the US and the euro area could be different. In particular, the announcements of the US quantitative easing policy did not always contain monthly volumes of purchases of securities, especially mortgage-based securities. On the other hand, the ECB announcements often contained monthly volumes of purchases of government securities, which could instantly shape market expectations and affect asset prices. The announcements of unconventional monetary policy measures affected the interest rates in the economy that was also confirmed in the works by K. Hausken, M. Ncube and R. Motto, C. Altavilla, G. Carboni [4, 20].

The work may be continued by studying the exchange rate dynamics depending on the quantitative easing policy on daily data. Also, the VECM model may be modified. It can be used, for example, to consider the ECB policy of zero interest rates which can be taken into account in different modes for the model. Another direction for further work may become the study of announcements regarding unconventional monetary policy measures that affect market expectations. However, this direction has been studied in more detail in the literature.

REFERENCES

1. Ferrari M., Kearns J. Monetary policy's rising FX impact in the era of ultra-low rates. *SSRN Electronic Journal*. 2017. DOI: 10.2139/ssrn.2917454
2. Clark P., MacDonald R. Exchange rates and economic fundamentals: A methodological comparison of BEERS and FEERS. IMF Working Paper. 1998;(67). URL: https://www.imf.org/external/pubs/ft/wp/wp9867.pdf
3. Krishnamurthy A., Nagel S., Vissing-Jorgensen A. ECB policies involving government bond purchases: Impact and channels. *Review of Finance*. 2018;22(1):1–44. DOI: 10.1093/rof/rfx053
4. Altavilla C., Carboni G., Motto R. Asset purchase programmes and financial markets: Lessons from the euro area. European Central Bank. Working Paper Series. 2015;(1864). URL: https://www.ecb.europa.eu/pub/pdf/scpwps/ecbwp1864.en.pdf

5. Diebold F., Nerlove M. The dynamics of exchange rate volatility: A multivariate latent factor ARCH model. *Journal of Applied Econometrics*. 1989;4(1):1–21. DOI: 10.1002/jae.3950040102
6. Meese R., Rogoff K. Empirical exchange rate models of the seventies: Do they fit out of sample? *Journal of International Economics*. 1983;14(1–2):3–24. DOI: 10.1016/0022–1996(83)90017–X
7. Dal Bianco M., Camacho M., Perez Quiros G. Short–run forecasting of the euro–dollar exchange rate with economic fundamentals. *Journal of International Money and Finance*. 2012;31(2):377–396. DOI: 10.1016/j.jimonfin.2011.11.018
8. Dedola L., Georgiadis G., Gräb J., Mehl A. Does a big bazooka matter? Central Bank balance–sheet policies and exchange rates. European Central Bank. Working Paper Series. 2018;(2197). URL: https://www.ecb.europa.eu/pub/pdf/scpwps/ecb.wp2197.en.pdf?57433fee929acc0a4165dafd2fd2064a
9. Engel C. The forward discount anomaly and the risk premium: A survey of recent evidence. *Journal of Empirical Finance*. 1996;3(2):123–192. DOI: 10.1016/0927–5398(95)00016–X
10. Bilson J. Recent developments in monetary models of exchange rate determination. *IMF Staff Papers*. 1979;26(2):201–223. DOI: 10.2307/3866509
11. Dornbusch R. Expectations and exchange rate dynamics. *Journal of Political Economy*. 1976;84(6):1161–1176. DOI: 10.1086/260506
12. Frankel J. On the mark: A theory of floating exchange rates based on real interest differentials. *The American Economic Review*. 1979;69(4):610–622.
13. Frankel J. Tests of monetary and portfolio balance models of exchange rate determination. In: Bilson J.F.O., Marston R.C., eds. Exchange rate theory and practice. Chicago: University of Chicago Press; 1984:239–260. URL: https://www.nber.org/chapters/c6837.pdf
14. Boeckx J., Dossche M., Peersman G. Effectiveness and transmission of the ECB's balance sheet policies. *International Journal of Central Banking*. 2017;13(1):297–333. URL: https://www.ijcb.org/journal/ijcb17q0a8.pdf
15. Adler G., Lama R., Medina J. Unconventional policies and exchange rate dynamics. *Journal of International Money and Finance*. 2019;95:402–423. DOI: 10.1016/j.jimonfin.2018.03.014
16. Engel C., Mark N., West K. Factor model forecasts of exchange rates. *Econometric Reviews*. 2015;34(1–2):32–55. DOI: 10.1080/07474938.2014.944467
17. Drobyshevsky S.M., Trunin P.V., The evolution of theory and practice of monetary policy as a result of the global economic crisis. *Zhurnal Novoi ekonomicheskoi assotsiatsii = Journal of the New Economic Association*. 2014;(4):141–158. (In Russ.).
18. Vashchelyuk N.V., Trunin P.V. Non-standard monetary policy measures: International experience and Russian practice. Moscow: Delo; 2016. 110 p. (In Russ.).
19. Krishnamurthy A., Vissing-Jorgensen A. The effects of quantitative easing on interest rates: Channels and implications for policy. *Brookings Papers on Economic Activity*. 2011;43(2):215–287. DOI: 10.1353/eca.2011.0019
20. Hausken K., Ncube M. Quantitative easing and its impact in the US, Japan, the UK and Europe. New York: Springer-Verlag; 2013. 123 p.

ABOUT THE AUTHOR

Artem A. Vinogradov — post-graduate student, Lomonosov Moscow State University, Moscow, Russia; Junior economist, Sberbank CIB, Moscow, Russia
artem.a.vinogradov@gmail.com

The article was submitted on 30.06.2019; revised on 17.07.2019 and accepted for publication on 20.07.2019. The author read and approved the final version of the manuscript.

APPENDIX

List of variables used in the models

Variables in the model	Variable description	Transformation	Source
infl_spr	Expected inflation from the difference in government bond yields indexed and non-indexed for inflation	Spread in monthly growth rates between countries	FRED, S&P Dow Jones Indices
st_int_spr	Yields at 3 monthly rates in the interbank market	Spread between countries	FRED
lt_int_spr	Yields on 10 year government bonds *	Spread between countries	FRED
M2_spr	M2 of the USA and euro area	Spread in monthly growth rates between countries	FRED, ECB
IP_spread	Indices of industrial production of manufacturing enterprises for the USA and euro area	Spread in monthly growth rates between countries	FRED
VIX	Index VIX	–	FRED
l_EuropeBrentSpotFOB	Brent oil price (FOB)	Logarithm	EIA
ld_EuropeBrentSpotPriceFOB	Brent oil price (FOB)	Differences of logarithms	EIA
l_ECB_purch	Volume of purchase of securities under the quantitative easing program of the euro area	Logarithm	FRED
l_US_purch	Volume of purchase of securities under the quantitative easing program of the USA	Logarithm	ECB
l_cumul_ECB_purch	Volume of purchase of securities under the quantitative easing program of the euro area	Logarithm of accumulated purchases for the entire sampling period	FRED
l_cumul_FED_purch	Volume of purchase of securities under the quantitative easing program of the USA	Logarithm of accumulated purchases for the entire sampling period	ECB
d_l_cumul_ECB_purch	Volume of purchase of securities under the quantitative easing program of the euro area	Differences of logarithms of accumulated purchases for the entire sampling period	FRED
d_l_cumul_FED_purch	Volume of purchase of securities under the quantitative easing program of the USA	Differences of logarithms of accumulated purchases for the entire sampling period	ECB
l_disparity	Consumer price indices in the US and the euro area	Logarithm of the ratio of price indices of the euro area to the US	FRED, ECB
d_l_disparity	Consumer price indices in the US and the euro area	Differences of logarithms of the ratio of price indices of the euro area to the United States	FRED, ECB

Note: * – weighted returns for euro area.

Source: compiled by the author.