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META-ANALYSIS: EFFECT OF FX INTERVENTIONS ON THE EXCHANGE RATE

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ABSTRACT

Today foreign exchange interventions (FXI) remain one the most relevant and widely used policy tool for most Central Banks. The research is aimed at assessing the short-run effect of Central bank foreign exchange market interventions on nominal exchange rate level and volatility. The investigation is conducted in a form of meta-analysis and based on estimates for 8 countries, extracted from 12 studies with a common monetary policy regime. The research suggests that there is no consensus in the literature about the underlying issue. Utilizing a random effects model, we have found that according to employed studies that Central Bank's FX interventions (USD sold) in the short run lead to local currency appreciation while increasing market volatility. However, these effects are close to zero. The validity of the results has been examined for publication bias by utilizing formal techniques.

Key words: foreign exchange interventions, exchange rate, monetary policy, meta-analysis
JEL classifications: C12, C83, E58, F31

1. Introduction

Since 2016 Ukraine has shifted to inflation targeting regime in conducting monetary policy with managed floating exchange rate. However, being a small open economy Ukraine is considered to be impacted by exchange rate shifts, which usually tend to be translated onto domestic price level and impacting targeted indicators. In such conditions, Ukraine monetary policy authority pays specific attention to choosing an appropriate instrument to stabilize the exchange rate. Today foreign exchange interventions (FXI) remain the most relevant and widely used policy tool for most Central Banks. While some recent studies claim that interventions may help to enhance welfare (Gabaix and Maggiori, 2015), there is a range of studies that doubt

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their effectiveness. Hence, assessing the magnitude and timing effect of one of the most popular Central bank instruments - foreign currency exchange market interventions - arises with severe importance.

This meta-analysis examines various FXI practices and its effects on exchange rate movements. We would like to investigate the possible effect both on the level and volatility of the exchange rate. For the analysis, we take into considerations those studies who research the cases similar to Ukraine, in particular, with sterilized interventions and floating exchange rate regime. As long as we only consider the papers with daily data frequency, this paper provides the evidence for short-run effects.

While many studies claim that actual interventions are often insignificant in their impact on exchange rate dynamics (if we consider their sizes), there is a theory which provokes the signaling function of the interventions. It states that the interventions may arise as an important signal for foreign exchange market participants. Therefore, our analysis of the impact of interventions separately compares the quantified amounts of interventions and the fact of interventions as a Central Bank's signal with the exchange rate fluctuations.

This study may help the National Bank of Ukraine define the objective of FXI and provides evidence of the effectiveness of this policy tool as a currency stabilizer.

The paper is constructed as follows. In section 2, we review the previous literature on the FXI effects on exchange rate dynamics. We continue in section 3 describing the articles used for the meta-regression analysis, the assumptions made to develop single criteria for further research, and the models used in chosen papers. In section 3 we present the methodology of our meta-analysis. There, we describe two approaches to weighing different studies.

2. Literature review

Meta-analysis is a research that is based on the previous investigations on the topic and targeted onto finding the consensus view on the research question.

In total 69 articles have been chosen for analysis, whereas only 12 of them have been utilized for the eventual meta-analysis after considering special attributes due to the possibility of the future comparison and summation of the studies' results. The reasons for excluding articles from the analysis were: absence of well-designed results (theoretical papers, including simulations); inapplicability of the result in meta-analysis due to the model specifics and/or dependent/independent variables under study, that couldn't be translated into unified form; low quality of paper and countries' specific factors.

Meta-analysis requires an article with a strong empirical base and results to put them into the model. However, there are some mainly theoretical papers under study in order to understand the idea behind interventions better. In "The foreign exchange market interventions of the European Central Bank"(2012) by M.Frenkel, C.Pierdzioch, G.Stadtmann there are many issues about interventions were observed, but one of the most important is sterilization. There are some measures, taken to neutralize expansionary or contractionary effects, but neutralization doesn't mean an absence of the effect at all and the article gives a flavour of these effects. It's an important topic because there are sterilized interventions mostly used throughout dozens of articles under investigation in the meta-analysis paper.

A very important factor, which influences the effect of FX interventions a lot (as long as the quality of the data and other minor factors), is a type of economy. An answer to this question could change things dramatically due to the difference in the problem set, that are facing a National Banks and society at all. A huge amount of papers under investigation did the analysis for the Japan and Latin America countries. It seems rather reasonable to observe two papers that correspond to these two cases because Japan is a developed economy and Latin America countries are emerging economies. In the "Central bank intervention and exchange rate volatility" by Kathryn M. Dominguez (1998), there are research about G-3 (US, Germany, Japan) central banks activity and the result here claims that exchange rate volatility could be affected by the interventions, however there is a division on the effect of secret interventions and announced interventions which would be discussed in the next section. In the first case, there is no effect as much, as in the second case and it could be explained by an absolutely different mechanism of expectations built by the publicity, which is based on the level of credibility of the central bank. The level of credibility depends on the level of the economy and there is some causality effect, like it shown in a series of studies where "Central Bank Independence and Transparency: Evolution and Effectiveness"(2008) by C.Crowe and E.Meade is one of them. Another paper, that contains most of the information about credibility in the last decade papers, which become a popular topic in the last 90s, is a "Central Bank communication and monetary policy: a survey of theory and evidence"(2008) by A.Blinder et al. In another case, with emerging economy, Herman Kamil in his "Is Central Bank Intervention Effective Under Inflation Targeting Regimes? The Case of Colombia" (2008) have shown that in the emerging economies market faces many breaks and changes, very aggressive intervention strategy and many more which gives a higher effect than in the developed economies. It is like a difference between a modern subway and a roller coaster, but they must have been done correctly anyway.

The model to make a research affects the result much, thus it must be chosen wisely. As we had noticed, there is a tendency to use GARCH-type models to investigate an effect of interventions. It is a relatively natural choice because we have a daily (very short run) data and necessity to observe a volatility mostly. More structural or OLS-type models concentrated on the long-run trends, which is not the best way to use for a high-frequency data, however, there is also some long-run effects of the interventions and they have to be examined too. Thus, the model is chosen based on the object of the research and it is nice to overview some of the cases. As far as GARCH-type are the most popular models in this segment of papers, we will begin with them. "Are Capital Controls and Central Bank Intervention Effective?"(2010) by Hernan Rincon and Jorge Toro is a paper, which investigates an effectiveness of different policies for depreciating the exchange rate and reducing its volatility in Colombia. There are about 4.5 thousand observations and, in order to use this information, authors evaluated AR(1)-GARCH(1,1) model where the dependent variable is an exchange rate return and there are lags, interventions, and taxes among independent ones. But the other point of interest of authors is a volatility, which is modeled by a long equation with interventions, taxes, their relationship, spread, and different lags. So, these two equations are with a minor difference, but the resulting significance of the corresponding coefficient is not similar. In this case, authors estimated, that coefficient near to interventions is insignificant in the case of mean and very significant in the variance of return. It is a great result because if they'd use regular OLS, it's quite possible to obtain an insignificance of interventions, while it is not the case in a reality (or, at least, with a GARCH approach) due to endogeneity issues. Another study in this sector is a "Does central bank interventions increase the volatility of foreign exchange rates?" (1993) by Kathryn M. Dominguez examined an intervention policy of Bundesbank and Bank of Japan in their intention to influence the level of exchange rate. There is an evidence of the high degree of volatility of the exchange rate in this period and it could be studied by an appropriate model, which is a GARCH in this case. Frankly speaking, it is one of the oldest papers in this meta-analysis and it is like the pioneer paper in the exploring of the exchange rate volatility. The GARCH was modeled in a manner to capture interventions in US, Germany, and Japan, daily and holiday dummies, news and secrecy dummies and their effect on the log of the spot exchange rate. The volatility was designed in the same manner, but it is capturing only different interventions and a news dummy. There are many results which are obtained from these model, but the important one is that there is a difference between the effect of the same interventions on the level and on the volatility, so as in the previous example. It is a very important finding which suggests about an importance of differentiating between level and volatility while studying exchange rate.

However, there is an absolutely different way to have a look at interventions and their effect. As would be shown in the next section it'd be examining long-run trends. The first example contains a very unusual Structural VAR model, which is used in order to have a look at the effect of an exogenous change in FX intervention via three structural shocks. It's described in the "Asymmetric effects of FX intervention using intraday data: evidence from Peru" (2013) paper by Erick Lahura and Marco Vega. In this model, it's necessary to put the long-run restrictions first (which is quite different to other studies in the very beginning because they examine short-run mostly), evaluate an SVAR and have a look on the results. For example, a positive exchange rate shock has a negative cumulative effect on dollar purchases and positive on sales which seems quite reasonable. This model doesn't contribute to the short-run understanding of the exchange rate as expected, according to the design. As well as the next example: DSGE model which is made to describe a Banco de la Republica FX intervention policy by H.Vargas, A.Gonzalez, and D.Rodriguez in their "Foreign exchange intervention in Colombia" (2013). In the best traditions of DSGE models, it contains about 30 different equations which give an opportunity to have a look over the different shocks influence on the economy under two different policies (aggressive and passive FX interventions policies). Interventions are modeled in the model in a way that deviation from the target of Real Exchange Rate leads to the corresponding intervention. And, at the very end of the section, it's nice to observe the simplest, but still, a very important method such as OLS using "The Effects of Japanese Foreign Exchange Market Interventions on the Yen/U.S. Dollar Exchange Rate Volatility" (2003) paper by M.Frenkel, C.Pierdzioch, G.Stadtmann. However, the appropriate use of such a technique could lead to the sensible result. Here the dependent variable is a logarithm of the ratio between the volatility of the exchange rate now and in the previous period, while the independent variables contain interventions and different other dummies and indexes. The result showed a significant effect of interventions on daily data, so this approach could be used as well, as the GARCH. So there are a great variety of models to observe interventions effect, which serves for different purposes which makes a wide field for the meta-analysis type research to evaluate results of different models groups.

Another important difference between the papers is a dataset. They were built differently for corresponding purposes. For example, structural models rely more on daily/weekly/monthly data while those, which examine volatility, use a daily or different type of intra-day data. For example, M. Taylor used a simple daily data in his "Is official exchange rate intervention effective?"(2003) to deal with the effect of official interventions, so as in the paper "The effectiveness of Central Bank Intervention in the EMS. The Post 1993 Experience"(2001) by P.Brandner, H.Grech, H.Stix. The reasoning to doesn't use more sophisticated, intra-day, data is an absence of identification of what type of transaction it is and misinterpret it, which could lead to the great bias. However, in other works with modern data, this problem is solved and authors were able to use more data. For example, in the "Central Bank Intervention and Exchange Rate Volatility: Evidence from Japan Using Realized Volatility"(2013) by A.Cheng, K.Das and T.Shimatani they've used a 5-minutes frequency data for computing daily variance, in other words to aggregate the data into something meaningful. The 5-minutes data itself couldn't be so useful in terms of modeling the effect of interventions because it is coming with some lag (which is different for agents), but, as long as the working paper statements are correct, it varies in the 1 day interval (depends on the working hours of different markets where Yen is in use and the difference in GMT).

One issue that arises widely in the papers is the difference between secret and public interventions and their effect on the exchange rate. S.Kim and A.Le in their "Secrecy of Bank of Japan's Yen intervention: Evidence of efficacy from intra-daily data" arises this question as the main of the paper and built a special model to investigate the difference between effects. It's a GARCH model which contains special terms for the public, secret rumored and secret undetected interventions in its mean and volatility parts. The difference between corresponding coefficients and their sign was the most important part of a paper. But there are other interesting points, such as news and events dummies like in "On central bank interventions in the Mexican peso/dollar foreign exchange market"(2013) by S.Garciaa-Verdu and M.Zerecero. They've estimated models, with variously designed dummies because it has an effect in the very short run and could affect volatility much. It could be an announcement for some intervention from CB or news like a problem with some goods that are exported from the country and many more. In this research dummies of this type have a significant effect and must be included in the model, if the data gives this opportunity. And the last but not least is a different additional object to study, such as a series of interventions, their amount and many more. It's done, for example, in "The effectiveness of FX interventions in four Latin American countries" (2012) by C.Broto. Dummies, mentioned above, are included in both mean and volatility in the GARCH model and their effect is quite significant. The idea behind the first in the series works in a news dummy manner, which gives a flavor of what will happen in the market in the nearest future, in another word it's an expectations building.

Articles in this research are rich for a different approach, objects of investigation and different values that might be counted in the total effect of interventions on the level of exchange rate. However, in the new paper, everything must be chosen wisely, it must take into account the data availability, country specialty, and other factors.

3. Data description

We have started our analysis from 69 articles, arriving at the eventual 12 articles based on the following criteria:

- nominal exchange rate under study;
- floating exchange rate regime;
- sterilized interventions;
- daily data frequency.

Restricting the sample of the articles in the research was necessary to proceed with comparable estimates for concluding on consensus effect across the studies.

Observations for the meta-analysis were taken from econometric models that can be summarized to the following general form:

- GARCH model and its modification:

$$log\left(\frac{e_{it}}{e_{it-1}}\right) = \beta_0 + \beta_1 \cdot I_{it-1} + \beta_2 \cdot X_i + \varepsilon_t,$$
$$\varepsilon_t = \varepsilon` * \sqrt{h_t}$$
$$h_t = \gamma_0 + \gamma_1 \cdot I_{t-1} + \gamma_2 \cdot X_i + \gamma_3 \varepsilon_{t-1}^2 + \gamma_4 h_{t-1}$$

where e – exchange rate (return), I – FX intervention, X – a vector of control variables, i and t – country (in the articles with estimations on multiple countries) and time indicators, respectively, ε – error term, $\varepsilon`$ – gaussian and h – variance (volatility as fitted values).

- OLS model:

$$log\left(\frac{e_{it}}{e_{it-1}}\right) = \beta_0 + \beta_1 \cdot I_{it-1} + \beta_2 \cdot X_i + \varepsilon_t$$

where e – exchange rate (return or volatility), I – FX intervention, X – a vector of control variables, i and t – country (in the articles with estimations on multiple countries) and time indicators, respectively, ε – error term.

We have investigated the idea of the impact of Central Bank interventions separately on exchange rate level and volatility. The total amount of estimates was divided into 2 groups: the ones that access the quantitatively distinguished impact of interventions (amount of intervention was normalized to 100 mln USD) and the ones that represent the impact of the fact of FX interventions without specifying the amount of the currency injected to/extracted from the market. The following table summarizes the total number of estimates for each dependent variable and specifies the form in which the dependent variable entered the model it was extracted from:

Table 1. Summary on obtained estimates for analysis

Dependent variable	How enters the model	# of observations
Level	return on the exchange rate in logarithm	13
Volatility (amount)	the difference in standard deviation in logarithm volatility, extracted from the GARCH model implied volatility on derivative instruments	17
Volatility (fact)	the difference in standard deviation in logarithm volatility, extracted from the GARCH model	5
Total		**35**

In the analysis, we utilize estimates on the association between exchange rate and Central bank interventions in the 8 counties, represented below. They consist of developed and developing countries with floating exchange rate and predominantly inflation targeting regime:

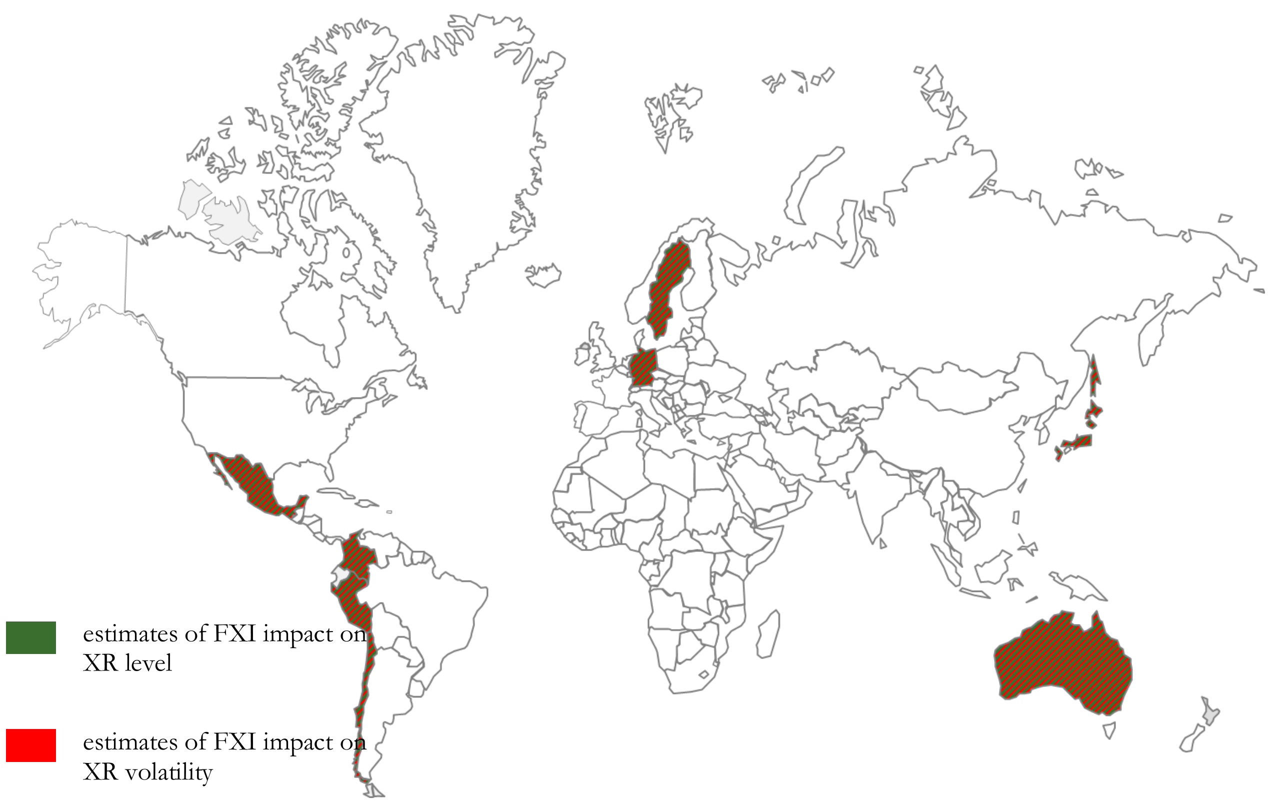

Figure 1. World map highlighting countries estimates for which used in the analysis

4. Methodology

Meta-analysis is a type of study that is targeted onto providing a consensus view on the research questions. There are two basic statistical models of performing meta-analysis: fixed-effects and random-effects models. They substantially differ in methodology and respectively diverse results.

- *Fixed effects model:* usage of this model presumes that there exists one true parameter for all studies and estimating results vary only due to sampling error. In our estimation we used the inverse variance fixed effect model, which uses inverse variance for weighting coefficients, collected from studies. The drawback of this model is in assigning large weights for a couple of estimates, which does not appear to be a problem only if one true parameter is considered for all studies. Formally, eligibility for using this model may be assessed through I-squared. High coefficient shows that there is substantial heterogeneity across the extracted estimates' true parameters and using the fixed effect model is inappropriate.

Formal model for fixed effects:

$$\overline{ES} = \frac{\sum w_{FE} * ES}{\sum w_{FE}}\ ,\ w_{FE} = \frac{1}{V_{ES}}$$

Where w_{FE} – weight assigned to the estimate, V_{ES} – variance of the estimate

- *Random effects model*: model implies different true parameter across the studies. According to Table 1 fixed effects model should not be used in the analysis due to large heterogeneity. This may be explained by the fact of collecting estimates from the variety of countries and time-periods with respective structurally different economic and monetary systems with local peculiarities.

Formal model for random effects:

$$\overline{ES} = \frac{\sum w_{RE} * ES}{\sum w_{RE}}\ ,\ w_{RE} = \frac{1}{V_{ES} + \tau^2}$$

where w_{FE} - weight assigned to the estimate, V_{ES} – variance of the estimate, τ – random variable.

In the analysis, we have divided the estimates obtained into two sub-samples for the further analysis:

- models, where FX Interventions entered in the amount (coefficients on interventions were transformed as of 100 mln USD intervention);

- models, where FX Interventions entered as the fact (dummy variable – 1 on the day of intervention).

Hence, the first model would highlight the consensus on the impact of the specific amount of foreign currency injected/extracted in/from the market, whereas the second would show the impact of the fact of intervention – the presence of Central bank on the market.

4.1. Publication bias

Since meta-analysis is the type of study that highly depends on the methods and means of extraction the results on the previous studies, the analysis should be checked any sources of bias. The common practice in meta-analysis is to check for publication bias. It is assessed through the existence of a correlation between the size effect of estimate and its precision or sample size, used in the particular study. Publication bias arises because of the tendency of publishing studies with some significant estimates of the results that coincide with mainstream theories. Publication bias is represented through a funnel plot, which consists of an estimate (partial correlation coefficient) on the x-axis and inverse standard deviation on the y-axis (Stanley et al, 2010). The symmetric funnel plot is an indication of no publication bias, whereas skewed funnel plot points to its existence. The existence of bias may be formally assessed through the Egger regression test, where normalized estimate regressed by its precision measure (Egger et al, 1997):

$$\frac{ES_i}{SE_i} = \beta_0 + \beta_1 \frac{1}{SE_i} + \varepsilon_i$$

In the case of insignificant betas, we claim no publication bias in the analysis.

5. Estimation results

Firstly, we assessed the effect of the specific amount of FX intervention on the exchange rate. Considering fixed effects model, the I-statistic has pointed onto large heterogeneity (of the true parameter) across the studies. Hence, consensus obtains on the basis of this model is not robust.

Table 2. Fixed effects model I-squared statistics

	I-squared	Fixed effect model
Level	99.80%	inappropriate
Volatility	99.90%	inappropriate

Source: authors' estimations

Random effects model estimation yields the following results:

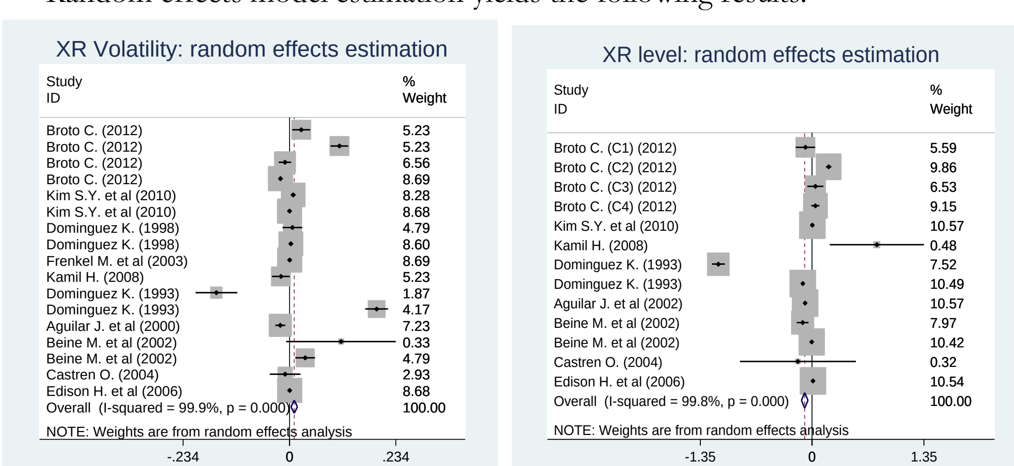

Figure 2, 3. Level (2) and volatility (3) random effects model

Source: authors' estimations

Across the analyzed studies there was no majority consensus on the sign of the effects as well as the magnitude. According to the random effect model estimates, consensus impact of 100 mln USD intervention (foreign currency sale) on local currency level was -0.1% (in period t+1), which may be treated as a neutral effect. However, results across the studies were very diverse, despite using common estimation techniques. For instance, Dominguez (1993) has found a significant negative effect of FX interventions on the exchange rate, with 100 mln intervention decreasing nominal exchange rate by more than 1.1%. On the contrary, Kamil (2008) estimated that the effect is positive and on average is 0.8%, but associated with relatively low significance.

The effect on volatility is even more cumbersome. On average each 100 mln USD intervention (absolute amount) increases volatility by 0.01%, which is close to zero and be neglected. One of the explanations, why FX interventions of Central Bank targeted onto volatility smoothing result in inverse effect – is that market participants receive a signal of worsened market conditions that necessitate treatment as CB enters the market, this adversely affects agents' expectations and increase uncertainty, as a result –volatility of exchange rate increases as well.

Table 3. Random effects model estimates

	Estimate	95% Confidence interval	
		Lower bound	Upper bound
Level	-0.089	-0.129	-0.048
Volatility	0.01	0.003	0.017

Source: authors' estimations

As the next step, the existence of publication bias should be examined. The following funnel plots represent the association between estimates (partial correlation coefficients) and the inverse standard deviation for the level and volatility estimates.

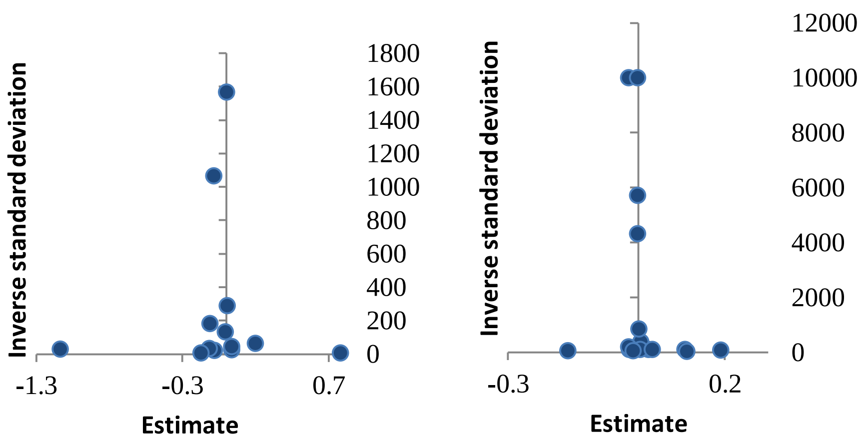

Figure 4,5. Level (4) and volatility (5) funnel plots

Source: authors' estimations

Whereas funnel plot for the impact of the intervention on the exchange rate level does not show the visual evidence of publication bias, the funnel plot for volatility appears to be slightly asymmetric – skewed to the right. However, it is worth mentioning that the publication bias is only one of the possible reasons for the skewed funnel plot (Sterne and Harbord, 2004). In case of high between-study heterogeneity (Table 1), the reason for skewed funnel plot may be indeed different true effect rather than publication or selection bias. Apart from the visual assessment of the existence of publication, we utilize the Egger regression test for both sets of estimates.

Table 4: Egger test results

	p-value	
	Constant (β0)	β1
Level	0.666	0.194
Volatility	0.493	0.781

Source: authors' estimations

According to Egger formal test, the regression coefficients are insignificant, that shows no evidence of publication bias in the analysis.

Our analysis consists of separate groups of estimates, the first one considers the impact of intervention depending on their amount on exchange rate level and volatility (highlighted above), whereas the second group assessed the fact on central bank's FX interventions on volatility.

Studies that investigated the impact of the fact of intervention on exchange rate volatility is scarcer. After employing the methodology that enables us to consider studies as comparable we arrive at 5 available estimates. I-statistic on the basis of fixed effects estimation if equal to 95%, that points onto large between-study heterogeneity and inappropriateness of utilizing fixed effects model.

Random effects model estimation yields the following results (including the previous results):

Table 5. Random effects model estimates

	Estimate	95% Confidence interval	
		Lower bound	Upper bound
Volatility	0.000	-0.012	0.013

Source: authors' estimations

According to the studies analyzed, we arrive at the neutral effect of the fact of intervention on the market volatility in consensus. Interestingly, K.Domingues studies – considering both amount and fact of intervention – show the significant positive effect of Central bank FX interventions. Whereas studies consensus is 0, the range of the estimates is quite wide, fluctuating from -0.015% to 0.317% impact on volatility including both estimates belonging to the same author, however different time frames.

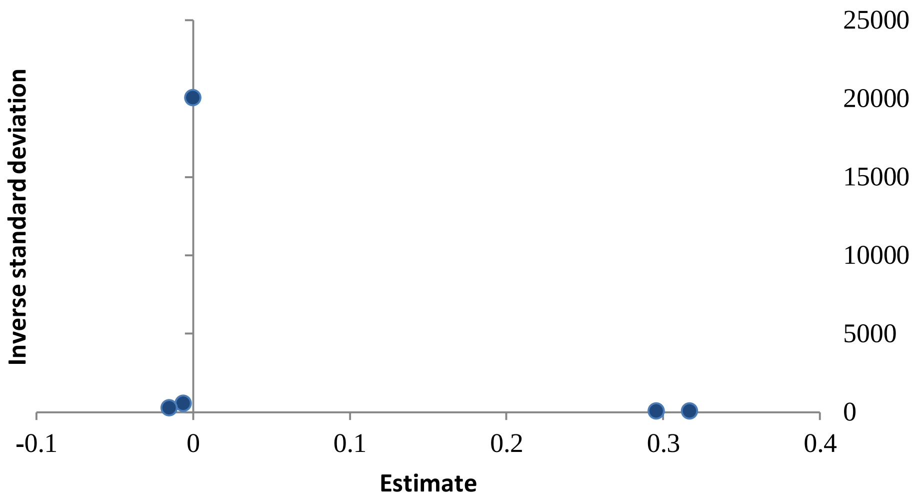

Figure 6. Level and volatility random effects model
Source: authors' estimations

6. Conclusions

The key research question of our meta-analysis is how does Central bank foreign exchange market interventions impact on nominal exchange rate level and volatility in the short run.

We have analyzed 12 articles about Central bank FX interventions in 8 countries (both – developing and developed) around the world with floating exchange rate (mostly IT regime).

According to our analysis, we may state that there is no general consensus in the literature about the sign and magnitude of impact on nominal exchange level. According to the random effect model estimates, because of 100 mln USD sale, local currency appreciates on average by 0.1%, which may be considered as neutral or no effect of the intervention on exchange rate level.

The effect on volatility is rather unexpected. On average each 100 mln USD intervention (absolute amount) increases volatility by 0.01%, which is close to zero and be neglected. One of the possible answers on why FX interventions of Central Bank targeted onto volatility smoothing result in inverse effect – is that market participants receive a signal of worse market conditions when Central Bank enters the market with FX interventions. This adversely affects agents' expectations and increase uncertainty, as a result – the volatility of the exchange rate increases as well.

Analysis of the fact of Central Bank intervention has yield also neutral result, though differing much across analyzed studies. Interestingly, K. Domingues studies – considering both amount and fact of intervention – show the significant positive effect of Central bank FX interventions. Whereas studies consensus is 0, the range of the estimates is quite wide, fluctuating from -0.015% to 0.317%.

Further analysis of the impact of Central Bank foreign currency market interventions on exchange rate may include:

• the analysis of central bank FX interventions on the exchange rate in the middle- and long-run;

• the differences of impact on the exchange rate between secret and publicly announced Central Bank's FX interventions.

Hence, there is no general consensus in the literature of Central Bank FX interventions on the exchange rate, albeit, estimations based on the random effects model yield in general neutral impact of interventions on exchange rate level and volatility in the short-run.

However, this topic could be quite useful for the Central Bank board as long as it is one of the main tools to affect the exchange rate and its volatility. There are a wide field of further investigation objects including the different effect of interventions secrecy, news and Central Bank openness, level of the economy under study (developed or emerging), other aspects that were observed during the articles mining. Different models for facets of interventions could help to decide whether or not the strategy and a view about them should be changed. So this meta-analysis is a significant basis for further research in this area.

Appendix A

Table 6. Aggregated data used for meta-analysis

Dependent	Estimate (PCC)	Standard error	Inverse standard error	Author	Year	Country
			Amount			
level	-0.08	0.06	16.67	Broto C. (C1)	2012	Chile
level	0.20	0.02	58.82	Broto C. (C2)	2012	Colombia
level	0.04	0.05	20.00	Broto C. (C3)	2012	Mexico
level	0.04	0.03	40.00	Broto C. (C4)	2012	Peru
level	0.00	0.00	1564.95	Kim S.Y. et al	2010	Japan
level	0.78	0.29	3.45	Kamil H.	2008	Colombia
level	-1.13	0.04	24.69	Dominguez K.	1993	Germany
level	-0.11	0.01	178.57	Dominguez K.	1993	Japan
level	-0.08	0.00	1062.70	Aguilar J. et al	2002	Sweden
level	-0.11	0.04	27.56	Beine M. et al	2002	German
level	0.00	0.01	129.79	Beine M. et al	2002	Japan
level	-0.17	0.36	2.80	Castren O.	2004	Japan
level	0.01	0.00	285.71	Edison H. et al	2006	Australia
volatility	0.03	0.01	100.00	Broto C.	2012	Chile
volatility	0.11	0.01	100.00	Broto C.	2012	Colombia
volatility	-0.01	0.01	142.86	Broto C.	2012	Mexico
volatility	-0.02	0.00	10000.00	Broto C.	2012	Peru
volatility	0.01	0.00	368.19	Kim S.Y. et al	2010	Japan
volatility	0.00	0.00	4310.34	Kim S.Y. et al	2010	Japan
volatility	0.01	0.01	90.09	Dominguez K.	1998	Germany
volatility	0.00	0.00	833.33	Dominguez K.	1998	Japan
volatility	0.00	0.00	10000.00	Frenkel M. et al	2003	Japan
volatility	-0.02	0.01	100.00	Kamil H.	2008	Colombia

volatility	-0.16	0.02	42.55	Dominguez K.	1993	German
volatility	0.19	0.01	78.13	Dominguez K.	1993	Japan
volatility	-0.02	0.01	180.83	Aguilar J. et al	2000	Sweden
volatility	0.11	0.06	16.22	Beine M. et al	2002	Germany
volatility	0.03	0.01	90.15	Beine M. et al	2002	Japan
volatility	-0.01	0.02	58.00	Castren O.	2004	Japan
volatility	0.00	0.00	5714.29	Edison H. et al	2006	Australia
			Fact			
volatility	0.30	0.07	15.16	Dominguez K.	Working paper	Germany
volatility	0.32	0.05	18.77	Dominguez K.	Working paper	Japan
volatility	-0.01	0.00	512.82	Garcia-Verdu S.	2014	Mexico
volatility	0.00	0.00	20000.00	Garcia-Verdu S.	2014	Peru
volatility	-0.02	0.00	250.00	Dominguez K.	1998	Germany

Appendix B

Table 7. Articles' description

Paper	Country	Period	Model	Perceived/ Official
Broto, C."The Effectiveness of FX Interventions in Four Latin American Countries" (2012)	Chile, Colombia, Mexico, Peru	1996 - 2011	GARCH	Perceived
Suk-Joong Kim; Anh Tu Le. "Secrecy of Bank of Japan's Yen intervention: Evidence of efficacy from intra-daily data" (2010)	Japan	1991 - 2004	AR-EGARCH	Official
Dominguez, K. "Central bank intervention and exchange rate volatility" (1998)	US, Germany, Japan	1977 - 1994	GARCH	Official
Frenkel, M.; Pierdzioch, C.; Stadtmann, G. "The Effects of Japanese Foreign Exchange Market Interventions on the Yen/U.S. Dollar Exchange Rate Volatility" (2003)	Japan	1993 - 2000	OLS (AR)	Official
Kamil, H. "Is Central Bank Intervention Effective Under Inflation Targeting Regimes? The Case of Colombia" (2008)	Colombia	2004 - 2006; 2007	2SLS, Tobit, GARCH	Official
Dominguez, K. "Does Central Bank intervention increase the volatility of foreign exchange rates?" (1993)	US, Germany, Japan	1985 - 1991	GARCH	Perceived
Aguilar, J.; Nydahl, S. "Central bank intervention and exchange rates: the case of Sweden." (2000)	Sweden	1993 - 1996	OLS, GARCH-M, SUR	Official
Beine, M.; Benassy-Quere, A.; Lecourt, C."Central bank intervention and foreign exchange rates: new evidence from FIGARCH estimations" (2002)	Germany, Japan	1985 - 1995	GARCH, FIGARCH	Perceived

Castrén, O. "Do options-implied RND functions on G3 currencies move around the times of interventions on the JPY/USD exchange rate?." (2004)	Japan	1992 - 2003	E-GARCH	Official
Edison, H.; Cashin, P.; Hong Liang."Foreign exchange intervention and the Australian dollar: has it mattered?." (2006)	Australia	1984 - 2001	GARCH	Official
Dominguez K. "When do CB FX interventions influence intra-daily and longer-term exchange rate movements?" (Working paper)	Germany, Japan	1989-1995	FIGARCH, OLS	-
Garcia-Verdu S. "Interventions and expected exchange rates in emerging market economies." (2013)	Mexico, Peru	2009-2013	OLS	-

Appendix C

Table 8. Group 1 (amount). Level, fixed effects estimation (Stata output)

Study	ES	[95% Conf.	Interval]	% Weight
Broto C. (C1) (2012)	-0.080	-0.198	0.038	0.01
Broto C. (C2) (2012)	0.200	0.167	0.233	0.09
Broto C. (C3) (2012)	0.040	-0.058	0.138	0.01
Broto C. (C4) (2012)	0.040	-0.009	0.089	0.04
Kim S.Y. et al (2010)	0.003	0.002	0.004	65.91
Kamil H. (2008)	0.782	0.214	1.350	0.00
Dominguez K. (1993)	-1.132	-1.211	-1.053	0.02
Dominguez K. (1993)	-0.111	-0.122	-0.100	0.86
Aguilar J. et al (2000)	-0.084	-0.085	-0.082	30.39
Beine M. et al (2002)	-0.113	-0.184	-0.042	0.02
Beine M. et al (2002)	-0.005	-0.020	0.011	0.45
Castren O. (2004)	-0.172	-0.873	0.530	0.00
Edison H. et al (2006)	0.011	0.004	0.017	2.20
I-V pooled ES	-0.024	-0.025	-0.023	100.00

Heterogeneity chi-squared=7106.03 (d.f.=12), p=0.000

I-squared (variation in ES attributable to heterogeneity) =99.8%

Test of ES=0: z=46.33, p=0.000

Table 9. Group 1 (amount). Volatility, fixed effects estimation (Stata output)

Study	ES	[95% Conf.	Interval]	% Weight
Broto C. (2012)	0.026	0.006	0.046	0.00
Broto C. (2012)	0.110	0.090	0.130	0.00
Broto C. (2012)	-0.010	-0.024	0.004	0.01
Broto C. (2012)	-0.020	-0.020	-0.020	39.66

Kim S.Y. et al (2010)	0.008	0.003	0.013	0.05
Kim S.Y. et al (2010)	0.000	-0.000	0.001	7.37
Dominguez K. (1998)	0.007	-0.015	0.028	0.00
Dominguez K. (1998)	0.003	0.001	0.005	0.28
Frenkel M. et al (2003)	0.000	0.000	0.000	39.66
Kamil H. (2008) (2002)	-0.019	-0.039	0.001	0.00
Dominguez K. (1993)	-0.161	-0.207	-0.115	0.00
Dominguez K. (1993)	0.192	0.167	0.217	0.00
Aguilar J. et al (2000)	-0.020	-0.031	-0.009	0.01
Beine M. et al (2002)	0.114	-0.007	0.234	0.00
Beine M. et al (2002)	0.035	0.013	0.056	0.00
Castren O. (2004)	-0.009	-0.043	0.024	0.00
Edison H. et al (2006)	0.000	0.000	0.001	12.95
I-V pooled ES	-0.008	-0.008	-0.008	100.00

Heterogeneity chi-squared=25355.72 (d.f.=16), p=0.000

I-squared (variation in ES attributable to heterogeneity) =99.9%

Test of ES=0: z=122.90, p=0.000

Table 10. Group 1 (amount). Level, random effects estimation (Stata output)

Study	ES	[95% Conf. Interval]		% Weight
Broto C. (C1) (2012)	-0.080	-0.198	0.038	5.59
Broto C. (C2) (2012)	0.200	0.167	0.233	9.86
Broto C. (C3) (2012)	0.040	-0.058	0.138	6.53
Broto C. (C4) (2012)	0.040	-0.009	0.089	9.15
Kim S.Y. et al (2010)	0.003	0.002	0.004	10.57
Kamil H. (2008)	0.782	0.214	1.350	0.48
Dominguez K. (1993)	-1.132	-1.211	-1.053	7.52
Dominguez K. (1993)	-0.111	-0.122	-0.100	10.49
Aguilar J. et al (2000)	-0.084	-0.085	-0.082	10.57
Beine M. et al (2002)	-0.113	-0.184	-0.042	7.97
Beine M. et al (2002)	-0.005	-0.020	0.011	10.42
Castren O. (2004)	-0.172	-0.873	0.530	0.32
Edison H. et al (2006)	0.011	0.004	0.017	10.54
D+L pooled ES	-0.089	-0.129	-0.048	100.00

Heterogeneity chi-squared=7106.03 (d.f.=12), p=0.000

I-squared (variation in ES attributable to heterogeneity) =99.8%

Estimate of between-study variance Tau-squared=0.0040

Test of ES=0: z=4.30, p=0.000

Table 11. Group 1 (amount). Level, random effects estimation (Stata output)

Study	ES	[95% Conf. Interval]		% Weight
Broto C. (2012)	0.026	0.006	0.046	5.23

Broto C. (2012)	0.110	0.090	0.130	5.23
Broto C. (2012)	-0.010	-0.024	0.004	6.56
Broto C. (2012)	-0.020	-0.020	-0.020	8.69
Kim S.Y. et al (2010)	0.008	0.003	0.013	8.28
Kim S.Y. et al (2010)	0.000	-0.000	0.001	8.68
Dominguez K. (1998)	0.007	-0.015	0.028	4.79
Dominguez K. (1998)	0.003	0.001	0.005	8.60
Frenkel M. et al (2003)	0.000	0.000	0.000	8.69
Kamil H. (2008) (2002)	-0.019	-0.039	0.001	5.23
Dominguez K. (1993)	-0.161	-0.207	-0.115	1.87
Dominguez K. (1993)	0.192	0.167	0.217	4.17
Aguilar J. et al (2000)	-0.020	-0.031	-0.009	7.23
Beine M. et al (2002)	0.114	-0.007	0.234	0.33
Beine M. et al (2002)	0.035	0.013	0.056	4.79
Castren O. (2004)	-0.009	-0.043	0.024	2.93
Edison H. et al (2006)	0.000	0.000	0.001	8.68
D+L pooled ES	0.010	0.003	0.017	100.00

Heterogeneity chi-squared=25355.72 (d.f.=16), p=0.000

I-squared (variation in ES attributable to heterogeneity) =99.9%

Estimate of between-study variance Tau-squared=0.0002

Test of ES=0: z=2.85, p=0.004

Appendix D

Table 12. Group 1 (amount). Level, Egger regression test

Source	SS	df	MS	Number of obs = 13 F(1, 11) = 1.91
Model	1214.52775	1	1214.52775	Prob > F = 0.1940
Residual	6980.82001	11	634.620001	R-squared = 0.1482 Adj R-squared = 0.0708
Total	8195.34776	12	682.945647	Root MSE = 25.192

w_estimate	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]
inverse_se	-.0207588	.0150056	-1.38	0.194	-.053786 .0122684
_cons	-3.563544	8.022572	-0.44	0.666	-21.22111 14.09402

Table 13. Group 1 (amount). Volatility, Egger regression test

Source	SS	df	MS	Number of obs = 13 F(1, 11) = 0.08
Model	2.23355834	1	2.23355834	Prob > F = 0.7811

Residual	302.900587	11	27.536417	R-squared = 0.0073 Adj R-squared = -0.0829
Total	305.134145	12	25.4278454	Root MSE = 5.2475

w_estimate	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
inverse_se	.0001392	. 0004887	0.28	0.781	-.0009364	.0012148
_cons	1.186173	1.67178	0.71	0.493	-2.493389	4.865735

Appendix E

Table 14. Group 2 (fact). Volatility, fixed effects estimation (Stata output)

Study	**ES**	**[95% Conf. Interval]**		**% Weight**
Dominguez K. (Working paper)	0.296	0.167	0.425	0.00
Dominguez K. (Working paper)	0.317	0.213	0.421	0.00
Garcia-Verdu S. (2014)	-0.006	-0.010	-0.002	0.07
Garcia-Verdu S. (2014)	-0.000	-0.000	0.000	99.92
Dominguez K. (1998)	-0.015	-0.023	-0.007	0.02
I-V pooled ES	-0.000	-0.000	0.000	100.00

Heterogeneity chi-squared=79.31 (d.f.=4), p=0.000

I-squared (variation in ES attributable to heterogeneity) =95.0%

Test of ES=0: z=1.52, p=0.129

Table 15. Group 2 (fact). Volatility, random effects estimation (Stata output)

Study	**ES**	**[95% Conf. Interval]**		**% Weight**
Dominguez K. (Working paper)	0.296	0.167	0.425	0.89
Dominguez K. (Working paper)	0.317	0.213	0.421	1.34
Garcia-Verdu S. (2014)	-0.006	-0.010	-0.002	33.25
Garcia-Verdu S. (2014)	-0.000	-0.000	0.000	34.35
Dominguez K. (1998)	-0.015	-0.023	-0.007	30.17
I-V pooled ES	-0.000	-0.012	0.013	100.00

Heterogeneity chi-squared=79.31(d.f.=4), p=0.000

I-squared (variation in ES attributable to heterogeneity) = 95.0%

Estimate of between-study variance Tau-squared=0.0001

Test of ES=0: z=0.04, p=0.966

Appendix F

Table 16. Group 2 (fact). Volatility, Egger regression test

Source	**SS**	**df**	**MS**	**Number of obs = 5** **F(1, 3) = 0.19**

Model	4.88020402	1	4.88020402	Prob > F = 0.6901
Residual	75.8532911	3	25.2844304	R-squared = 0.0604
				Adj R-squared = -0.2527
Total	80.7334952	4	20.1833738	Root MSE = 5.0284

w_estimate	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
inverse_se	-.0001247	.0002838	-0.44	0.690	-.001028	.0007786
_cons	.9392471	2.53983	0.37	0.736	-7.143626	9.02212

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