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Transmission of euro area shocks to Central and Eastern European countries. Implications for monetary autonomy problem and business cycles synchronization.

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ABSTRACT

This paper uses the VAR methodology to analyse the effects of European Central Bank monetary policy shocks and euro area output and inflation shocks on the European Union member states from Central and Eastern Europe. First, we look at the strength of effects of identified euro area monetary policy shocks and compare the influence with the one of the domestic policy shocks. Next, we turn to analysis of output and inflation responses to euro area output and inflation shocks relative to aggregate euro area reaction. We provide implications for each country monetary policy decision process and draw conclusions concerning readiness for euro adoption, both from monetary and real economy point of view.

Keywords: monetary policy shocks, VAR, international transmission, business cycles, EMU enlargement

JEL Classification: E52, F42, F36

1. Introduction

In the globalizing world where effects of policy and economic changes in one country increasingly affect other countries, the international transmission of monetary policy shocks, especially from US, has drawn attention of many economists. However, it seems plausible that European Central Bank's (ECB) policy influence also goes beyond euro area borders. Especially, the neighbouring countries from Central and Eastern Europe (CEE) seem to be susceptible to such spill-overs due to factors such as their close trade and financial ties with the euro area, relative small size and relatively high openness of these economies.

Based on this background, the main aim of this paper is to investigate the effects of euro area monetary policy shocks on CEE economies and to determine the strength of ECB's policy impact as compared to domestic policy one. Additionally, we study also the effects of euro area output and inflation shocks. In order to present that, we estimate a VAR models for chosen CEE countries which have not adopted the common currency yet.[1]

Studying the effects of both monetary and real economy shocks has important implications. First, the effects of euro area shocks on CEE economies provide information to the countries' central banks. While analysing domestic economic situation and making decisions on the monetary policy, central banks have to take into consideration all variables plausible for the task. Showing the effects of foreign variables and monetary policy on the domestic economy says how useful developments in euro area can be for domestic economy analysis and policy making.

By studying countries of both floating and flexible exchange rate regimes, we are also able to bring new evidence on a theory of monetary autonomy. The impossible trinity theorem states that monetary autonomy can supposedly be only achieved when country resigns from controlling its exchange rate. However, there also exist studies implying that, outside few largest economies, countries do not have much monetary freedom regardless of exchange rate regime (see, for instance, Frankel et al., 2004). We want to re-examine that problem.

What's more, the extent to which CEE countries are affected by euro area shocks is important for future euro adoptions.[2] When it comes to monetary policy, the more a country is affected by ECB's monetary policy decisions now, before euro adoption, the lower should be a cost of giving up its own monetary policy when it joins the monetary union. What's more, dissimilar reactions of output and inflation to the common monetary policy make the central bank the cause of asymmetric shocks and thus, the monetary policy works against instead of in

favour of the existence of monetary union. Such situation would also nullify the benefit of monetary union in form of elimination of domestic monetary policies as sources of country idiosyncratic shocks.

The reactions of domestic variables to euro area output and inflation shocks, on the other hand, inform us about business cycle synchronization, the problem underlined by OCA theory. For monetary union to be sustainable, countries should not be affected by asymmetrical shocks which make carrying out of monetary policy difficult since it cannot fit well countries with divergent business cycles. Therefore, we consider responses to euro area output and inflation shocks that are consistent with aggregate euro area reactions as important condition for future success of enlarged euro area.

The main advantage of the paper approach, when compared with enormous literature on monetary union sustainability, is that its estimation is not just about OCA theory and business cycles synchronization, but that it also studies the monetary shock transmission. We believe that both issues are important in the context of euro adoption, making up two sides of the same coin. Moreover, the paper includes rarely seen comparison between influences of ECB monetary shocks and domestic monetary shocks, thanks to which it is possible to check the scope of ECB's control over the economy as compared to domestic central banks.

This analysis is especially interesting in the light of recent euro adoption in Latvia (January 2014) and Lithuania (January 2015) well as discussions on the subject in Poland, Czech Republic and Hungary. Even though the outbreak of euro area crisis halted the prospects of prompt euro adoption, the talks on the subject did not disappear completely and are recursively coming back in many countries.

The rest of the paper is structured as follows. Section 2 presents the literature review. Section 3 contains empirical model description. Section 4 describes data and sample periods. Section 5 reports empirical analysis results. Section 6 concludes and provides policy implications.

2. Literature review

Our study on the euro area monetary policy and macroeconomic shocks effects bases largely on the Optimal Currency Area (OCA) theory on the costs and benefits of common currency, started with Mundell (1961), McKinnon (1963), and Kenen (1969). The European

Commission publication from 1990 evaluates these benefits and costs of forming economic and monetary union in the context of the European countries. Using various methodologies, many empirical studies in this field concentrate mainly on the problem of business cycles synchronization and speed of shock adjustment, to name Bayoumi and Eichengreen (1994) as example.

Our research bases on the large literature using Vector Autoregression models to study macroeconomic effects of unexpected changes in interest rates. The use of VAR to study monetary policy, which started from the seminal work of Sims (1980), concentrated first on the US economy. Christiano et al. (1998) constitute for a review of research on what happens after exogenous shock to monetary policy in the US and research methodology.

There are also many studies analysing the monetary policy effects in the euro area as a whole or its individual countries. Most of them encompass a period prior to euro introduction. Peersman and Smets (2001) construct synthetic data for euro area in order to derive impulse-response functions for the monetary union as a whole. They also estimate responses of various real and financial variables as well as individual countries' output and prices to the identified euro area monetary policy shock. Mojon and Peersman (2001) analyse individual countries for the period 1980-1998. They divide countries in respect to their monetary integration with Germany and study responses to either domestic or German monetary policy shock. Peersman (2004) looks at the impact of common monetary policy shock on chosen euro area member states, taking into consideration spill-over effects across countries.

Another strand of the literature we base on concerns international transmission of monetary policy shocks. Such studies concentrate almost solely on transmission of US interest rate shocks on different groups of countries. Kim (2001) takes the non-US, G-6 countries and presents detailed evidence of the effects of US monetary policy and the transmission mechanism behind them. The main results show that while US expansionary monetary policy leads to booms in other countries, the main role in the transmission is played not by changes in the trade balance but rather by the decrease in the world interest rate. Kim and Yang (2012) study the transmission of US monetary policy shocks to the East Asian countries while taking into consideration their exchange rate regimes and eventual capital controls. Their results contradict expectations in that they find strong responses of domestic interest rates of the countries with floating exchange rate regime while these responses in fixed exchange rate regimes are much

weaker. As the possible reasons, they state fear of floating in the former group of countries and capital controls in the latter.

For the connected topic of monetary autonomy and exchange rate regimes, one must mention Frankel et al. (2004). They construct Hendry's general unrestricted model to examine whether the exchange rate regime choice influences sensitivity of local interest rates to the changes in international one, taking for the international rate US money market rate and also German money market rate in some cases. They find that even in countries with floating exchange rate regimes, the full transmission cannot be rejected in the long run. They find evidence for monetary autonomy only in few biggest industrial economies.

There exists also some literature using VAR models for transmission of euro area shocks to Central and Eastern European countries. However, it concentrates mainly on business cycle shocks. Fidrmuc and Korhonen (2003) as well as Horvath and Rátfai (2004) use Blanchard and Quah (1989) identification strategy to identify euro area output and demand shocks in order to study shock correlations across chosen euro area countries and New Member States (NMS).

In the field of the transmission of monetary policy shocks, Eickmeier and Breitung (2006) construct structural factor model and identify euro area supply shock, euro area real demand shock, and a common monetary policy shock to study cyclical synchronization of euro area and NMS.

There exists also a group of research about domestic monetary policy transmission in Central and Eastern European countries. Ganev et al. (2002) is one of the first to carry out a cross-country comparison of reactions to domestic interest rates and exchange rates shocks in ten CEE countries. They carry out Granger causality tests and impulse-response analysis and state that in most countries exchange rate channel is stronger and more stable than interest rate channel.

3. Empirical methodology

We use VAR framework to analyse the effects of European Central Bank's monetary policy shocks and euro area output and demand shocks in chosen European Union countries from Central and Eastern Europe.

The basis of our identification strategy is an assumption that euro area variables are not influenced by any variables of a single country from Central and Eastern Europe. We think that

such an assumption is plausible since most of the countries of the region are relatively small compared to the euro area as a whole.[3] While the situation in some non-euro Central European countries might affect macroeconomic variables of neighbouring small euro area countries, like Estonia or Slovakia, it is hard to believe it can have any influence on the average euro area data.

Based on such assumptions, we construct structural block-exogenous VAR model of the representation:

$G(L)y_t = e_t$

where: G(L) = $\begin{bmatrix} G_{11}(L) & 0 \\ G_{21}(L) & G_{22}(L) \end{bmatrix}$, $y_t = \begin{bmatrix} y_{1t} \\ y_{2t} \end{bmatrix}$, $e_t = \begin{bmatrix} e_{1t} \\ e_{2t} \end{bmatrix}$,

G(L) is matrix polynomial in lag operator L. Vector y_t constitutes of endogenous variables: y_{1t} is vector of euro area variables, y_{2t} is vector of CEE countries variables. e_t is vector of structural disturbances. $G_{12}(L) = 0$ is a restriction of block-exogeneity which means that y_{1t} is not affected by current as well as lagged values of y_{2t}.

The reduced-form of our VAR model has the representation:

$y_t = B(L)y_{t-1} + u_t$

where: B(L) = $\begin{bmatrix} B_{11}(L) & 0 \\ B_{21}(L) & B_{22}(L) \end{bmatrix}$, $y_t = \begin{bmatrix} y_{1t} \\ y_{2t} \end{bmatrix}$, $u_t = \begin{bmatrix} u_{1t} \\ u_{2t} \end{bmatrix}$

B(L) is matrix polynomial in lag operator L. Vector y_t constitutes for endogenous variables: y_{1t} is vector of euro area variables, y_{2t} is vector of CEE countries variables. u_t is a vector of serially uncorrelated reduced-form disturbances with a mean zero and a covariance matrix Σ_u. We use Choleksy decomposition of the reduced-form covariance matrix to identify structural innovations.

Because explanatory variables differ in some equations of the VAR equation system, OLS estimations provide inefficient estimates. Thus, we use seemingly unrelated regressions (SUR) method to estimate the reduced form block-exogenous model.

Thanks to such identification method, the identified euro area shocks are identical for all the countries under consideration which greatly facilitates cross-country comparison. It also has an advantage of saving degrees of freedom as compared to the full two-country model.

First, we construct a block of euro area variables which we use to identify the euro area shocks. We follow Peersman and Smets (2001) and include in the block data for euro area aggregate output, inflation, money market short term interest rate and real effective exchange rate. We also add one more variable to the system – economic sentiment survey data – in order

to control for market sentiments. The market sentiments tell not only about present situation but also about future expectations of market players towards economic situation. As central banks are supposed to look not only at past variables but also at their forecasts, we believe that including market economic sentiment data helps in controlling for these future values. What's more, according to European Central Bank's institutional framework, it looks at various economic variables while deciding on its policy stance. Since it would be impossible to include in our VAR specification all the variables that ECB might be taking into consideration, we assume that economic sentiment data account for good summary of all these data. Therefore, we have a five-variable euro area block with the ordering being: output, inflation, economic sentiment indicator, short term interest rate and real effective exchange rate to identify the euro area structural monetary policy and macroeconomic shocks.

In the next step, we construct very similar block for each CEE country. Our block for each CEE consists of domestic output, inflation, money market short term interest rate and exchange rate to euro.

In each VAR specification we also include additional variables exogenous to both euro area and domestic blocks: world commodity price index and US short-term nominal interest rate. Inclusion of exogenous variables is practice in many VAR specifications and is justified by the literature with a need of controlling for changes in world demand and inflation. This necessity comes from the "price puzzle" problem, i.e. the situation in which after positive interest rate shock, the VAR model results point at price level increase. Sims (1992) argues that such a problem may stem from the fact that central bank has more information about predicted future inflation than is included in simple VAR and proposes inclusion of exogenous variables (commodity price index in his case) as a means to at least partially solve this problem. Many euro area VARs include also US output and federal funds rate (e.g. Peersman & Smets, 2001) as well. Introducing federal funds rate as exogenous variables has one more important implication – it helps us to control for changes in US monetary policy, which affect both euro area and CEE countries, and thus concentrate on the transmission of the pure ECB shocks.

4. Data and sample periods

This section describes data we use in the empirical analysis as well as sample periods for the analysed countries.

4.1. Data

We use data of monthly frequency. The indicator of output is industrial production index excluding construction. Inflation is measured with harmonized index of consumer prices (HICP), all-items index. Interest rate used in case of euro area is average monthly observations of EONIA. For CEE countries we use monthly averages of day-to-day money market interest rates provided by Eurostat. The real effective exchange rate of euro area is based on consumer price indices of 42 trading partners as deflator. The exchange rate towards euro is formed as price in national currency for 1 euro. The economic sentiment in euro area is measured with Economic Sentiment Indicator, being a weighted average of the components of the confidence indicators for industry, services, consumers, construction, and retail trade provided by European Commission DG ECFIN. The data for euro area are taken from ECB databases, while the data for CEE countries are taken from Eurostat. Only data on industrial production for Czech Republic are taken from IMF IFS database. For world variables we use All Commodity Price Index including both fuel and non-fuel price indices from IMF and US federal funds effective rate taken from Datastream.

All data are seasonally adjusted and in their logarithms (except for interest rates) and in levels. Therefore, we allow for implicit co-integration relationships in the data. However, as Sims, Stock, and Watson (1990) state, we still achieve consistent estimates of the parameters.

We estimate all VAR models with 4 lags. The value was chosen based on Akaike statistic run for the euro area block specification. Admittedly, the theory points at longer lag order, as central banks are supposed to take into consideration data from the period longer than only last four months. However, some of our sample periods are quite short and there is a large number of coefficients to be estimated in each equation, so with the choice of longer lag order we would run out of degrees of freedom fast.

4.2. Sample periods

Sample period varies for each country and its length depends on the starting day for the latest exchange rate regime. In many CEE countries we can observe changes in the exchange rate regimes after system transformation in the beginning of 1990s, as many of the countries were using exchange rate as means for stabilization of internal economic situation and were looking for regime best suited to their needs and economic conditions.

Table 1. The exchange rate regimes in Central and Eastern European countries from 1990s and starting point for estimation periods.

Country	Dates	Regime	Sample period
Bulgaria	Feb 1991-Jul 1997 July 1997	Floating Currency board - first to DM, then to euro	From Jan 2000 (due to data availability)
Czech Republic	May 1993-Feb 1996 Feb 1996-May 1997 From May 1997	Hard peg Peg with fluctuation margins +/- 7% (basket DM 65%, USD 35%) Managed float and inflation targeting (from Dec 1997)	From July 1997[4]
Hungary	Until Jun 2001 Jun 2001-Feb 2008 From Feb 2008	Narrow band peg (ecu/euro 70%; only euro from January 2002) Flexible peg to euro with wide fluctuation band and inflation targeting Managed/free float and inflation targeting	From Jun 2001[5]
Latvia	Feb 1994-Dec 2004 From Jan 2005	Peg to SDR Peg to euro with +/- 1% bands	From Jan 2005
Lithuania	Apr 1994-Feb 2002 From Feb 2002	Fixed peg to USD Currency board towards euro	From Feb 2002
Poland	Until May 1995 May 1995-Apr 2000 From Apr 2000	Fixed exchange rate: crawling basket peg with decreasing crawl Crawling peg with widening corridor (basket: USD 45%, DM 35%) Free float and inflation targeting	From Apr 2000

On the whole, we can observe two patterns of exchange rate regime setting and changes in Central and Eastern Europe. For the first group of countries that operate now under floating exchange rate regime (Czech Republic, Hungary, Poland), the first choice of the regime after transition was usually some type of a hard peg. Then, they gradually eased exchange rate controls, achieving managed float or free float regime. The second group of countries (Bulgaria, Latvia, Lithuania) operates now under fixed exchange rate regime. In case of Baltic countries, that was the choice made soon after gaining independence and only base currency changed later. In Bulgaria, the government first opted for floating exchange rate regime which was then

replaced with a currency board. The more detailed history of exchange rate regimes in CEE is showed in Table 1 together with the starting days of our estimation samples for each country.

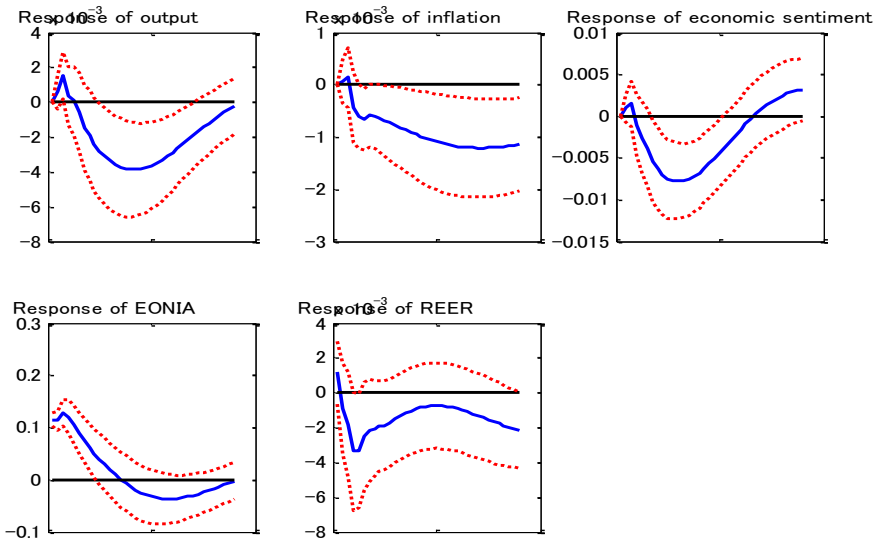
5. Results

This section presents results of our empirical study. First, the responses of countries' output, inflation, and interest rate to euro area and domestic monetary policy shocks are presented. Next, we analyse again the relative strength of both of the shocks based on variance-covariance decomposition analysis. After that, euro area output and inflation shocks' effects are examined. All the studied impulse-response functions present reactions up to 36th month after the shock.

5.1. Monetary policy shocks

First, we present the reactions of euro area aggregate variables to common monetary policy shock. As we can see at Figure 1, impulse response functions in most cases follow expectations and results from the previous research. The output starts falling with few months lag, with the negative impact deepening for the next year, then recovering slowly and almost reaching zero at the end of considered period. It also takes inflation 2-3 months to react, after which it falls with the impact staying persistent. We also observe fall in economic sentiment after interest rate increase but it recovers quicker and becomes positive after around 25 months. Only for the

Figure 1. Responses of euro area aggregate variables to euro area monetary policy shock



Note: Solid lines: impulse response functions; dotted lines: bootstrapped 90% confidence bands

exchange rate the results are not consistent with the previous research and expectations that after the positive interest rate shock the appreciation of a currency takes place. In our case we have small appreciation at the impact but soon after that the index starts falling, and the depreciation of the currency takes place.

Next, we report the impulse response functions of CEE countries variables to the EONIA shock identified with the block-exogenous model. Blue lines at Figure 2 present impulse response functions of CEE countries' output, inflation, and interest rate to euro area monetary policy shocks. Because the character of exchange rate regime can potentially have big influence on the monetary policy transmission, while reporting the results we take into consideration whether country has fixed or floating exchange rate regime. We compare the countries within and between the groups.

Looking at the results for the six Central and Eastern European countries while taking into consideration their exchange rate regime, we can observe high similarity of impulse responses for the countries with fixed exchange rate regime. The group of countries with floating exchange rate is more diversified. For all the countries, from both groups, the most similar is the reaction of the output. In all cases the output starts falling few months after the shock and the reaction stays negative for most of or the whole period under consideration.

Figure 2. Responses of CEE countries' output, inflation and interest rate to euro area and domestic monetary policy shocks

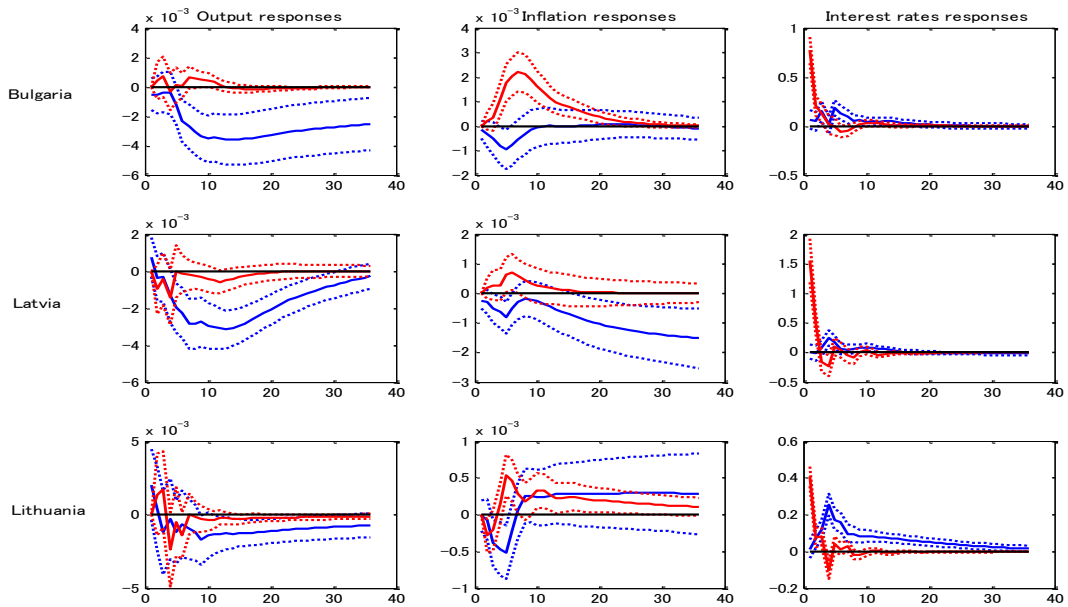
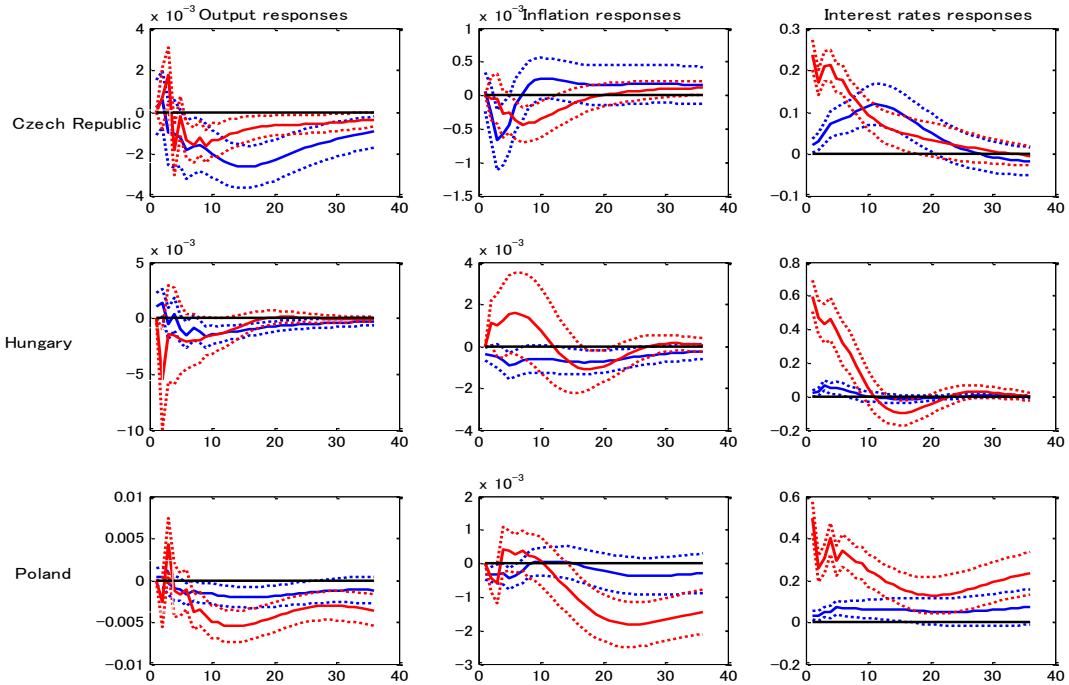


Figure 2 (continued)



Note: Solid lines: impulse response functions (blue – reaction to euro area monetary policy shock; red – reaction to domestic monetary policy shock); dotted lines: bootstrapped 90% confidence bands

While the output responses are quite uniform for all the countries, there are bigger differences in the responses of inflation. Only in case of Hungary, Latvia, and Poland the reaction stays negative for the whole period. In the remaining countries, after few months of declining inflation rate, it starts rising or the reaction becomes zero.

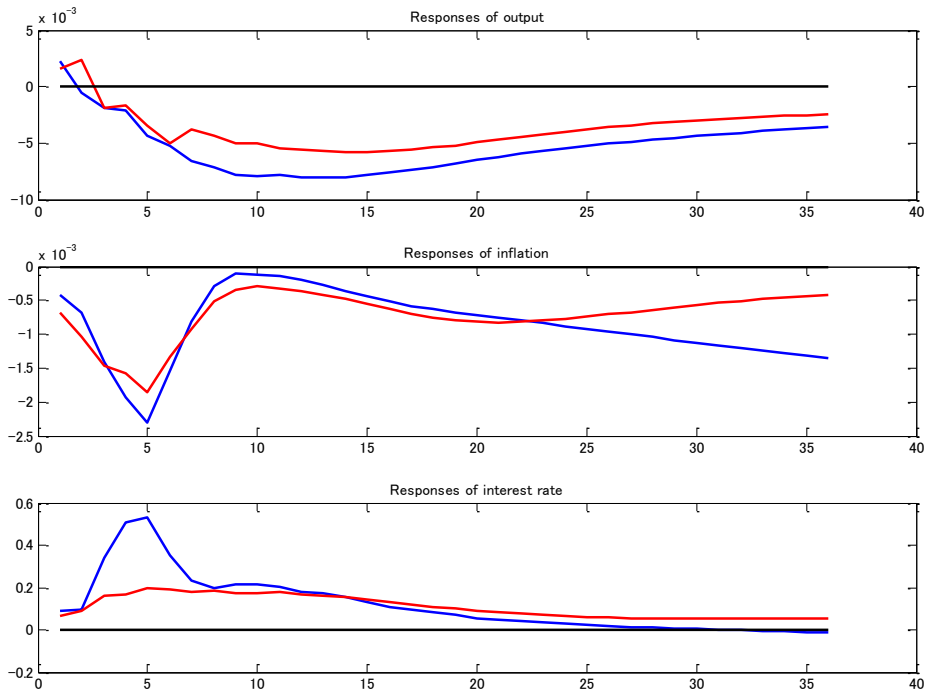
In all countries with fixed exchange rate as well as in Hungary we can observe quick rise in the interest rate after the shock with most of the effect disappearing in just few months. Only in Czech Republic we have slower growth at first and the effect disappearing much slower. Poland stands out even more with the positive effect on the interest rate not fading down for the whole considered period. That result may seem a bit surprising as according to the impossible trinity theorem we would rather expect more significant and larger rise of interest rate in countries with fixed exchange rate and small and/or insignificant increase for floaters. Therefore, these results confirm the previous research conclusions that even the countries with floating exchange rate regime are not characterized with much monetary autonomy.

In order to have a better outlook at the scale of differences in foreign monetary shocks

transmission between flexible and fixed exchange rate regime countries, we study the average responses for each group of countries. Figure 3 presents average impulse response functions to EONIA shocks for the two groups. We can observe that on the whole, results show similar patterns between the fixed and floating exchange rate regimes. There is mainly the difference in the magnitude of the reactions. The output falls deeper for fixed exchange rate regimes. Inflation fall is similar for both groups. Interest rate shows higher increase for fixed exchange rate regimes but the reaction is slightly more persistent in the floating countries.

The results follow the expectations that transmission of foreign monetary policy shocks is stronger in fixed exchange regime countries though one might have expected higher differences. However, with the exchange rate reacting freely to foreign shocks, the shocks' effects on the economy should be not only weaker but also slower. In our case, there is no evidence on the reactions in floating countries being more sluggish, as also shown for instance by Canova (2005).

Figure 3. Average responses to euro area monetary policy shocks for fixed and floating exchange rate groups of countries



Note: Average impulse response functions; blue line: fixed exchange rate regime countries, red line: floating exchange rate regime countries

The analysis up till now shows us that euro area monetary policy shocks have high influence on the domestic variables of CEE countries. Thus, the question arises how this influence compares with the effects of domestic monetary policy. In order to check this, we go back to Figure 2 where we plot responses to EONIA shocks (blue lines) against responses to domestic monetary policy shocks (red lines). In order to carry out comparisons of the two effects, we normalize both shocks so that they have equal magnitude of one. The analysis of the impulse-response functions with their confidence bands shows us that there are many significant differences between effects of EONIA and monetary policy shocks. This is especially the case for the output variable which usually falls deeper after euro area monetary policy shock. The biggest exceptions would be Hungary where the responses to both shocks are very similar and Poland where domestic policy effects are stronger. Inflation is falling more after EONIA shock in Bulgaria, Latvia, and Hungary but differences are usually not statistically significant. One of the reasons for this is placed in the very wide confidence bands on most of inflation responses. When it comes to the interest rate, the initial response is naturally higher after domestic interest rate shocks but EONIA shocks have often more persistent effects. However, especially in Poland, but also in Hungary and Czech Republic to some extent, we observe considerably stronger effects of domestic shocks.

These results imply that euro area monetary policy shocks not only have an important influence on CEE countries' macroeconomic variables but also that in many cases this influence seems to be stronger than influence of domestic monetary policy. This shows what a difficult situation the central banks of these countries face when it comes to carrying out their monetary policy and deciding on their policy stance. What's more, these results do not clearly depend on whether the country functions under fixed or flexible exchange rate.

5.2. Variance-covariance decomposition

After looking at impulse response functions which show the direction of responses to the shocks, we again study the relative strength of euro area and domestic monetary policy effects using at variance-covariance decompositions of the domestic variables due to mentioned shocks. Table 2 shows the percentage of the variance in each variable explained by EONIA shocks as compared to domestic interest rate shocks 12, 24, 36 months after the shock as well as the maximum values reached within 36-month period.

For most of the countries, EONIA is responsible for much larger part of output variance than domestic interest rate. Only for Poland we observe close values. What's more, the influence of EONIA is usually increasing with the time, reaching maximum in the third year after the shock, while domestic interest rate's impact is usually highest in the first year after the shock and then the impact gradually falls. Only in case of Poland the maximum of domestic influence is reached much later – in 25th month.

The situation in case of inflation is more diverse. While only for Bulgaria we observe higher influence of domestic interest rate, the differences between EONIA and domestic rate shocks are divergent across countries. In Czech Republic, Lithuania, and Poland, the EONIA rate influence is only slightly higher. Hungary and Latvia (to some extent) show much higher percentage of inflation variance explained by EONIA in comparison to domestic interest rate.

The maximum values for domestic interest rate shocks are naturally much higher in case of its own shock than EONIA one. Therefore, we concentrate on the variance decompositions estimated for 12th, 24th and 36th month after the shock only. The results imply that in Bulgaria, Hungary and Latvia it is domestic interest rate shocks that influence most of interest rate variance. The EONIA shocks have only small, additional impact. Also in Poland domestic interest rate impact is higher but the difference is not as decisive as in aforementioned countries. In Lithuania EONIA's impact is higher. However, in here both euro area and domestic interest rate play very important role, explaining together over 70% of domestic interest rate variance. Only in case of Czech Republic in the longer run EONIA's shocks start explaining slightly higher variance than domestic interest rate shocks.

Based on the results of variance decomposition analysis, we can confirm that euro area monetary policy shocks have important influence on domestic variables and that this influence is often higher than the one of domestic monetary policy. There are, however, some differences across the analysed countries. It is also hard to observe any patterns connected to exchange rate regime and relative strength of euro area and domestic monetary policy shocks.

Table 2. Variance-covariance decompositions of CEE countries' output, inflation and interest rate due to euro area and domestic monetary policy shocks

Output	Bulgaria		Czech Republic		Hungary		Latvia		Lithuania		Poland	
Shocks	Euro area	domestic	Euro area	domestic	Euro area	domestic	Euro area	domestic	Euro area	domestic	Euro area	domestic
12	8.20	0.25	4.11	1.25	6.50	1.42	9.47	0.36	2.40	1.39	6.07	5.09
24	11.75	0.14	9.38	1.18	9.06	1.34	15.64	0.32	4.01	1.38	13.03	9.24
36	12.56	0.11	9.75	1.12	9.29	1.28	15.07	0.29	4.79	1.37	12.99	9.07
max	12.56	0.34	9.78	1.27	9.29	1.66	15.72	0.69	4.79	1.49	13.30	9.25

Note: Percentage of variables' variance explained by the shocks 12, 24 and 36 months after the shock as well as the maximum value reached within 36 months period.

Table 2 (continued)

Inflation	Bulgaria		Czech Republic		Hungary		Latvia		Lithuania		Poland	
Shocks	Euro area	domestic	Euro area	domestic	Euro area	domestic	Euro area	domestic	Euro area	domestic	Euro area	domestic
12	1.98	19.22	3.17	1.22	8.40	1.46	2.68	0.85	3.57	3.58	3.18	0.45
24	1.53	16.83	2.72	0.92	10.49	1.41	4.63	0.30	4.05	3.13	2.31	4.06
36	1.45	15.83	2.44	0.75	10.41	1.23	6.81	0.16	5.14	2.98	3.72	7.22
max	3.07	19.41	3.81	1.23	10.60	1.80	6.81	1.35	5.14	3.74	8.09	7.22

Interest rate	Bulgaria		Czech Republic		Hungary		Latvia		Lithuania		Poland	
Shocks	Euro area	domestic	Euro area	domestic	Euro area	domestic	Euro area	domestic	Euro area	domestic	Euro area	domestic
12	8.05	58.18	14.78	21.45	6.41	49.99	5.73	65.85	41.16	40.09	11.64	35.44
24	7.82	52.38	13.82	12.70	6.44	46.01	5.54	60.89	42.85	34.28	8.43	16.53
36	7.49	50.11	12.95	11.82	6.34	45.35	5.42	57.95	41.37	32.04	8.79	14.43
max	8.22	95.20	15.12	91.26	8.12	90.52	5.83	96.01	43.09	91.96	12.98	84.23

5.3. Euro area output and inflation shocks

Until now our analysis concentrated solely on transmission of monetary policy shocks. However, the close economic ties of CEE countries with euro area let us think that not only monetary but also other shocks might have significant impact on these economies. Therefore, in this section we present the impulse response functions of CEE domestic variables to euro area output and inflation shocks. That will let us draw further conclusions regarding dependence of these small open economies on economic developments in their neighbouring area.

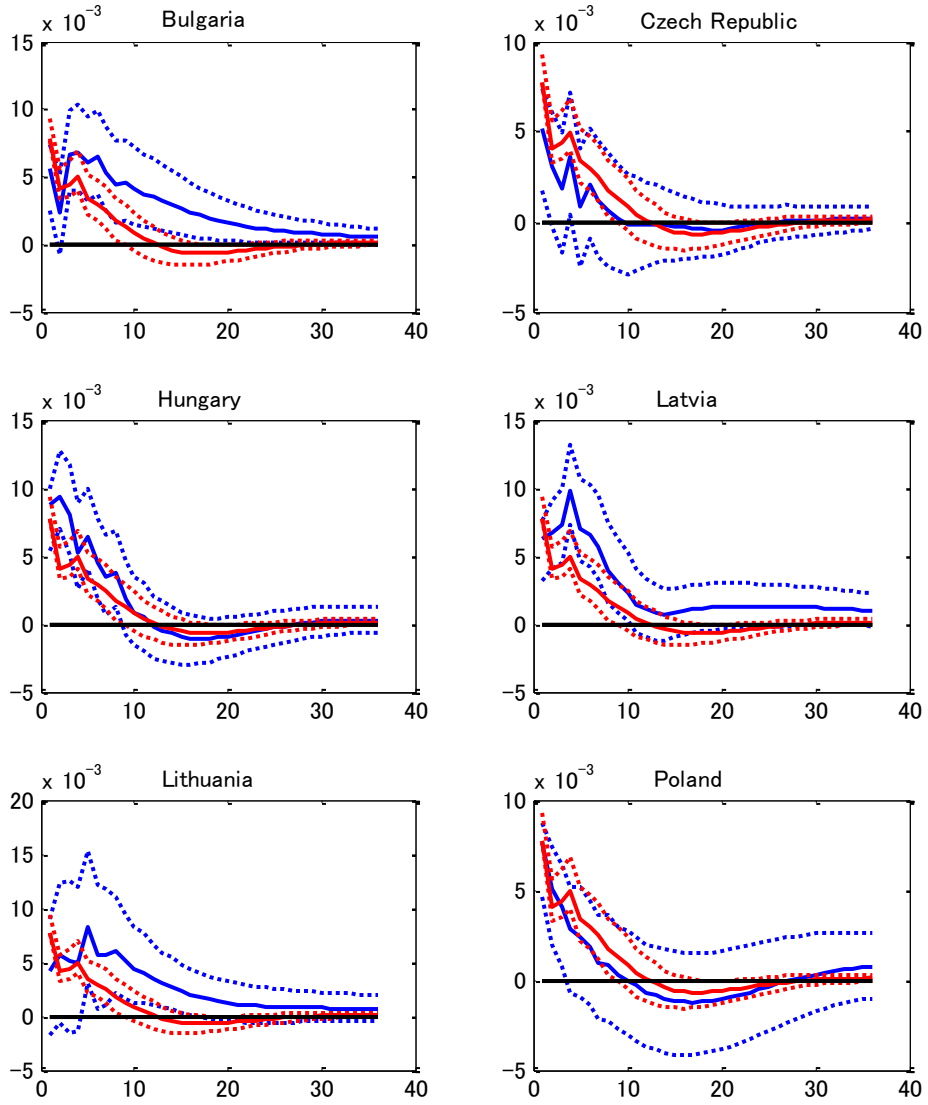
Figures 4a-d present responses of each country output and inflation to euro area output and inflation shocks as compared to aggregate euro area reactions. In order to facilitate comparisons, all estimations are based on equal sample periods which start in February 2002. After euro area positive output shock we observe instant increase in output in all CEE countries. The exact size and persistence of that increase differ across the countries but it usually is not significantly different from the aggregate euro area reaction. Output increase is higher than euro area output rise especially in case of Bulgaria and Lithuania and rather similar or lower in other countries.

After euro area positive output shock euro area inflation increases for around two years. On the other hand, in most of CEE countries inflation shows movements in opposite direction. The differences between each country response and aggregate euro area response are, however, usually not significant (with short exception in Bulgaria). The main reason for that are the very wide confidence bands on CEE countries' inflation responses, showing that it is hard to predict how the inflation really changes after euro area output shocks.

The euro area inflation shock causes slight fall in aggregate output. CEE countries react differently. In all the countries increase in output can be observed and in many cases the difference with euro area response is statistically significant. What's more, the responses of CEE countries are largely similar across the countries. Though, naturally there are slight differences in exact strength of reaction.

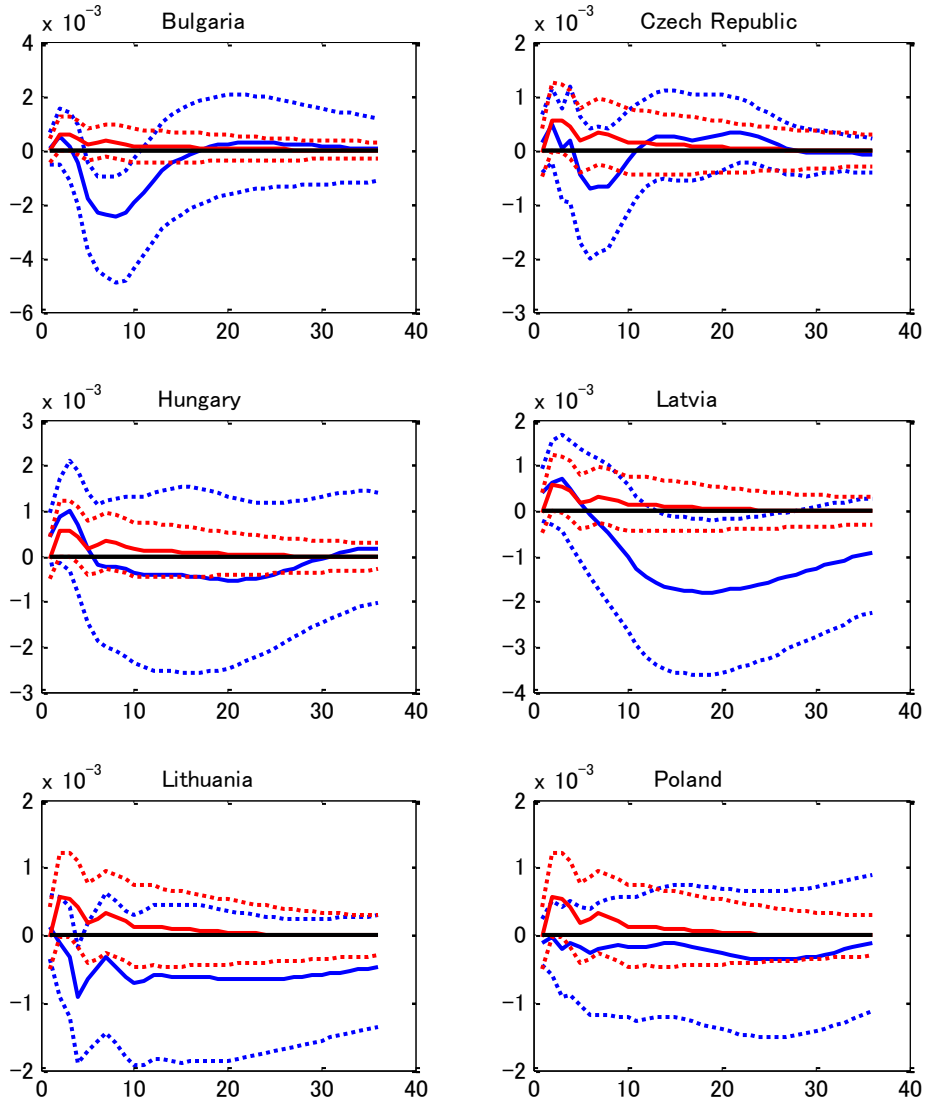
After positive inflation shock in euro area we also observe increase in inflation in CEE countries. In Czech Republic, Latvia, and Lithuania the reactions are especially similar to the aggregate euro area one. Hungary and Poland show significantly stronger inflation hikes, at least for some period after the shock. In Bulgaria, after initial fall in inflation, the response becomes similar to aggregate euro area one in the second year after the shock.

Figure 4a. Responses of CEE countries' output to euro area output shock



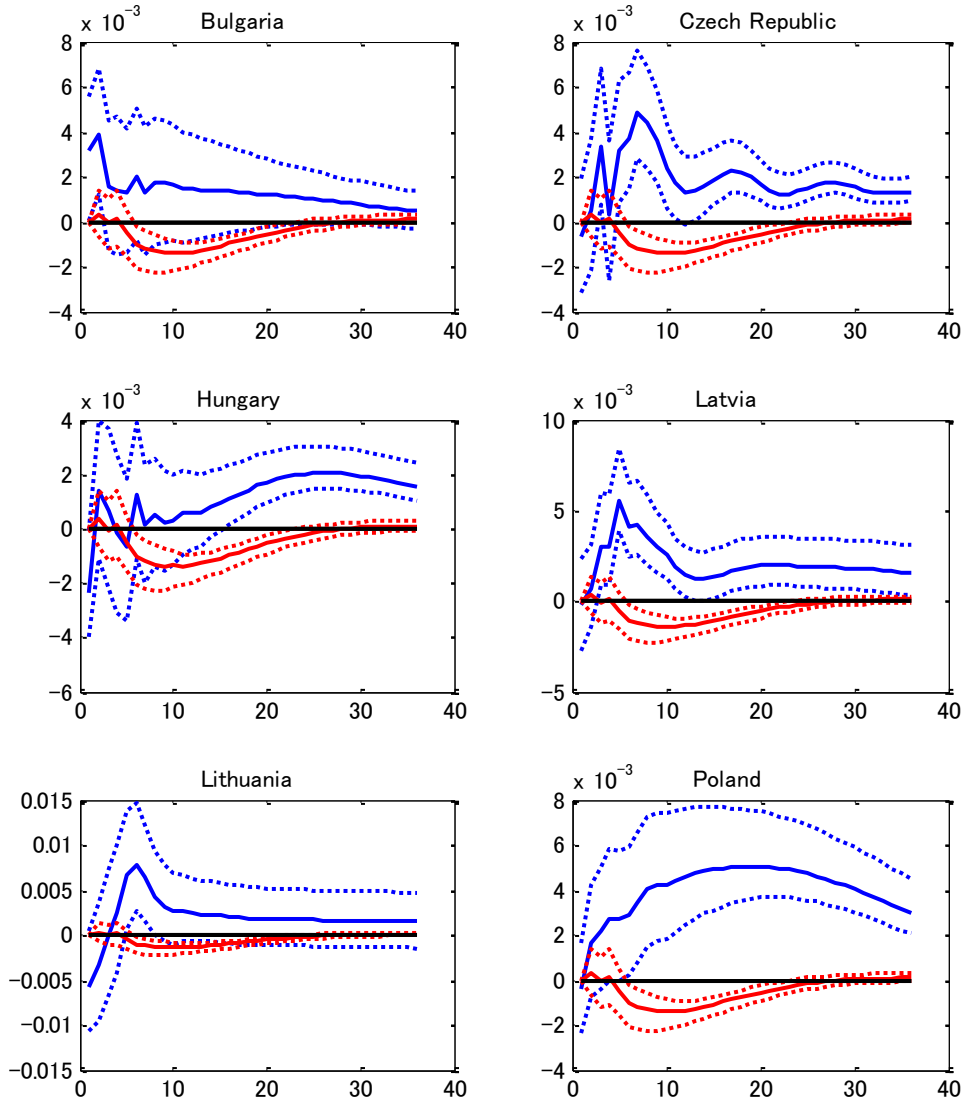
Note: Solid lines: impulse response functions (blue – responses of each CEE country variable; red – response of aggregate euro area variable); dotted lines: bootstrapped 90% confidence bands

Figure 4b. Responses of CEE countries' inflation to euro area output shock



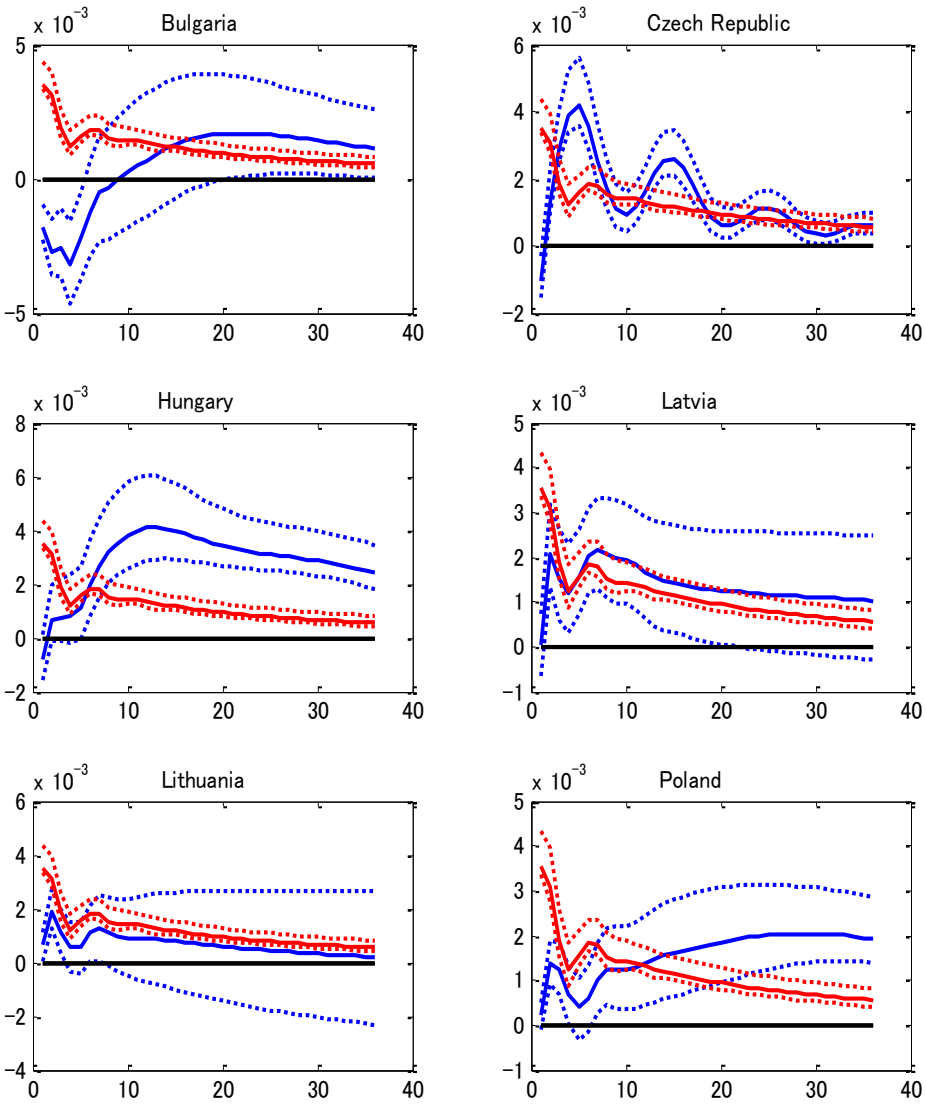
Note: As Figure 4a

Figure 4c. Responses of CEE countries' output to euro area inflation shock



Note: As Figure 4a

Figure 4d. Responses of CEE countries' inflation to euro area inflation shock



Note: As Figure 4a

Summing up, euro area output and inflation shocks have an important, often statistically significant influence on output and inflation in CEE countries. While comparing countries' responses with the average euro area one, we observe mixed results. The euro area responses of output and inflation after their own respective shocks are placed somewhere in the middle of the CEE countries responses. In the remaining cases, we observe opposite reactions in euro area and CEE countries. In case of response of output to euro area inflation shock, the euro area

variable's reaction is negative and CEEs' output response is positive. While the average euro area reaction is slightly positive after euro area output shock, in most CEE countries inflation reacts negatively.

5.4. Robustness results

In order to assure the robustness of our results, we also carry out additional estimations checking two main assumptions of our model. Table 3 contains chosen results of that exercise – 12th and 24th period responses of output and inflation to the considered shocks[6].

First, we estimate the models using variables in differences instead of levels. Even though many studies follow opinion of Sims, Stock, and Watson (1990) and use data in levels even if they are non-stationary, there also exist arguments for and cases of using differenced data (e.g. Miyao, 2000). The first observation we make on the results is a fact that the impulse responses estimated with variables in differences do not die out to zero, with the possible reason being the fact that this specification might not be stationary VAR model due to inability to impose possible co-integrating relations. Aside of that, we can observe some sign and results' significance differences as compared to benchmark specification. However, even in this situation, the main observations and conclusions do not change significantly.

Second, we check the influence of the chosen order of variables on the results. In order to do that, we estimate generalized impulse response functions (GIRFs) which do not depend on the order of variables in VAR model. The results, and thus main conclusions, are very close to benchmark specification. What's more, we confirm benchmark results with, not reported in here, model estimations using Cholesky decomposition but for few different orderings of variables.

Table 3. Responses to euro area shocks. Benchmark and alternative specifications.

Shock/ specification		Country						
EONIA shock	Output	EA	Bul.	Czech Rep.	Hung.	Lat.	Lith.	Pol.
benchmark	12	**-0.0016**	**-0.0035**	**-0.0024**	**-0.0013**	**-0.0031**	**-0.0013**	**-0.0019**
	24	**-0.0008**	**-0.0030**	**-0.0018**	**-0.0006**	**-0.0014**	**-0.0010**	**-0.0016**
differences	12	0.0343	-0.0011	-0.0087	-0.0089	0.0062	-0.0259	0.0094
	24	0.0645	0.0051	-0.0038	-0.0015	0.0213	-0.0163	0.0114
GIRFs	12	**-0.0146**	**-0.0515**	**-0.0366**	**-0.0313**	**-0.0663**	**-0.0118**	-0.0160
	24	**-0.0095**	**-0.0547**	**-0.0251**	**-0.0176**	**-0.0368**	**-0.0082**	**-0.0199**

EONIA shock	Infla-tion	EA	Bul.	Czech Rep.	Hung.	Lat.	Lith.	Pol.
benchmark	12	**-0.0002**	0.0000	0.0002	**-0.0007**	-0.0005	0.0003	0.0001
	24	**-0.0001**	0.0001	0.0002	**-0.0006**	**-0.0012**	0.0003	-0.0004
differences	12	**-0.0088**	**-0.0220**	**-0.0120**	-0.0064	-0.0146	**-0.0403**	-0.0136
	24	**-0.0085**	**-0.0226**	-0.0107	-0.0098	-0.0204	**-0.0407**	-0.0183
GIRFs	12	-0.0016	0.0215	-0.0024	-0.0246	0.0171	**0.0238**	0.0162
	24	-0.0007	0.0038	0.0034	**-0.0392**	**-0.0674**	**0.0244**	-0.0329
EA output shock	**Output**	**EA**	**Bul.**	**Czech Rep.**	**Hung.**	**Lat.**	**Lith.**	**Pol.**
benchmark	12	0.0065	**0.3524**	-0.0197	-0.0240	0.1075	**0.3473**	-0.0708
	24	**-0.0314**	**0.1134**	-0.0136	-0.0384	0.1250	0.0897	-0.0519
differences	12	**1.0598**	**1.2210**	**0.9940**	**1.5285**	**1.4565**	**0.9364**	**1.0041**
	24	**1.0040**	**1.1520**	**0.9280**	**1.4804**	**1.2530**	**0.9202**	**0.9731**
GIRFs	12	0.0410	**0.1588**	0.0554	-0.0420	**0.0932**	0.0797	-0.0627
	24	-0.0199	**0.0473**	-0.0060	-0.0128	**0.0897**	0.0244	-0.0005
EA output shock	**Infla-tion**	**EA**	**Bul.**	**Czech Rep.**	**Hung.**	**Lat.**	**Lith.**	**Pol.**
benchmark	12	0.0126	-0.1142	0.0138	-0.0417	-0.1469	-0.0606	-0.0166
	24	0.0012	0.0252	0.0228	-0.0456	**-0.1626**	-0.0655	-0.0358
differences	12	**0.0928**	**0.3219**	0.1267	0.1448	0.1835	0.0103	-0.0416
	24	**0.0970**	**0.3570**	0.1260	0.1698	0.2221	0.0238	-0.0253
GIRFs	12	0.0126	-0.1848	0.0146	-0.0881	**-0.2726**	**-0.2094**	-0.1246
	24	-0.0107	0.0847	0.0377	-0.1131	**-0.3269**	**-0.1796**	-0.1999
EA inflation shock	**Output**	**EA**	**Bul.**	**Czech Rep.**	**Hung.**	**Lat.**	**Lith.**	**Pol.**
benchmark	12	**-0.1335**	0.1465	0.1325	0.0610	**0.1436**	0.2454	**0.4606**
	24	-0.0214	0.1035	**0.1334**	**0.2013**	**0.1944**	0.1688	**0.4828**
differences	12	-0.0678	0.1069	0.0789	-0.3316	0.0411	-0.3630	0.0128
	24	-0.0811	0.1122	0.0559	-0.3339	0.0435	-0.4212	0.0518
GIRFs	12	**-0.0943**	0.0221	0.0230	**0.0410**	**0.0522**	**0.0394**	**0.1597**
	24	**-0.0524**	0.0074	**0.0349**	**0.0686**	**0.0605**	**0.0330**	**0.1620**
EA inflation shock	**Infla-tion**	**EA**	**Bul.**	**Czech Rep.**	**Hung.**	**Lat.**	**Lith.**	**Pol.**
benchmark	12	**0.1311**	0.0683	**0.1626**	**0.4080**	**0.1677**	0.0899	**0.1376**
	24	**0.0813**	**0.1659**	**0.1084**	**0.3127**	0.1182	0.0477	**0.1981**
differences	12	**0.1875**	-0.0200	0.0831	0.0084	-0.0070	0.1395	-0.0734
	24	**0.1991**	-0.0192	0.0641	0.0349	-0.0397	0.1394	-0.0501
GIRFs	12	**0.1146**	**0.1300**	**0.1762**	**0.3435**	**0.1331**	**0.1377**	**0.1884**
	24	**0.0917**	**0.1864**	**0.1276**	**0.2514**	**0.0803**	0.0796	**0.3233**

Note: Point estimates of impulse responses for output and inflation in 12th and 24th month after the shock; values in bold indicate responses significantly different from zero based on the bootstrapped 90% confidence intervals

6. Conclusions and implications

In this paper we employ VAR methodology in order to study empirically the dependence of CEE economies on changes in euro area monetary policy as well as macroeconomic conditions. The results point at strong influence of euro area money market interest rate shocks on the economies under consideration which is also often higher and more prolonged than domestic interest rate shocks' influence. What's more, euro area output and inflation shocks are important drivers of changes in domestic variables. Though, some reactions of CEEs variables to these shocks are dissimilar to the aggregate euro area responses.

The results of the analysis let us draw few important conclusions and implications. First, there is the importance of the exchange rate regime in keeping monetary autonomy. Strong interest rate reactions even in the countries with floating exchange rate regimes confirm the results of previous research stating that even floaters do not have much monetary autonomy. Moreover, the reactions of macroeconomic variables after ECB's monetary policy shock show very similar patterns for both fixed and floating exchange rate countries. These results confirm low importance of exchange rate regime in foreign shock transmission and therefore the need to use other criteria for the choice of exchange rate regime.

The results we achieve imply that central banks of floating exchange rate regime Central and Eastern European countries should take into consideration European Central Bank's monetary policy as well as euro area output and inflation shocks while deciding their own policy stance. Also in fixed exchange rate countries, where monetary policy rule is more automatic, it is important to estimate detailed influence of changes in economic and monetary conditions in euro area on each country. In all the countries euro area variables seem useful indicators in forecasting future changes of domestic policy goals as well as macroeconomic conditions - the information that central banks should not ignore. Additionally, in floating countries this is to avoid the situation when the economy is depressed or stimulated too much through simultaneous ECB's and national central bank's policy changes.

Our analysis lets us also draw some implications regarding the future euro adoptions in Central and Eastern European countries. Most of them are common for both floating and fixed exchange rate countries. Quite high, on average, influence of euro area shocks, dependence of domestic interest rate on changes in EONIA as well as strong response of macroeconomic variables to euro area output and inflation shocks can serve as argument for euro adoption in

most CEE countries.

On the other hand, however, divergent inflation responses and large standard deviations for inflation reactions can pose potential problems after euro adoption. The reason is the fact that ECB's main objective lies in inflation and not output stabilization. Therefore, uncertain and divergent changes in inflation rate can make implementation of common monetary policy extremely difficult, if not impossible. As de Grauwe (2009) points out, different economic conditions in monetary union countries can bring the situation where ECB has no reason for interest rate changes because the average rate of inflation in euro area will always be between actual inflation rates in individual countries.

This situation, however, might also be more harmful to CEE countries than ECB policy making process. ECB might not change its policy even after the countries adopt euro due to relatively small size of these economies.[7] That means ECB's monetary policy decisions often not fitting economic situation in the countries, leading to further destabilization of the economy. Especially, divergent inflation rates together with common nominal interest rate lead to differences in real interest rates across countries. Too high real rates might excessively depress the economy, while too low might lead to unsustainable booms at asset markets. Recent years have already given us examples on these cases, proving the danger to be more than just theoretical deliberation. Therefore, there exists a need for detailed country-specific study on risks of euro adoption connected to the role of real interest rate in the economy.

There exist also some implications connected to euro adoption decision depending on country's exchange rate regime. While in case of fixed exchange rate regime the shock transmission after euro adoption might not change significantly, loss of floating exchange rate regime might constitute for important structural break in transmission mechanism. That means the need for further analysis of the role of floating exchange rate and the effects of euro adoptions in these countries, which however exceeds the scope of this paper.

NOTES

1. As the data we use end in year 2013, we include to our non-euro CEE countries Latvia which adopted euro in January 2014 as well as Lithuania which adopted euro in January 2015.
2. Guiso et al. (1999) state three main conditions for common monetary policy to be successful. First, the countries should have common goals, which in case of EMU are guaranteed by treaties and ECB status. Second, countries should have similar business cycles to minimize possibility of asymmetric shocks. And third, the monetary transmission mechanism in each country should work in the similar way.

3. The only possible exception, we believe, might be Poland, being the largest economy in Central and Eastern Europe and population-wise the 6th largest country in the European Union. However, for the sake of uniformity of our identification strategy for all the countries and, therefore, also the easiness of comparisons, we maintain our basic assumption also for this country.
4. In May 1997 a currency crisis occurred in Czech Republic, being one of most important reasons for implementation of floating regime. Due to the crisis the interest rates grew to unusually high levels with the effects still visible in June 1997. Therefore, we exclude these two months from our sample period.
5. We argue that the change to managed float regime in February 2008 does not constitute a break due to the fact that already from June 2001 Hungary pursued inflation targeting, and its peg to euro was very flexible.
6. Due to space restrictions, the results of robustness tests in form of derived impulse response functions are not included into the paper but are available from the author upon request.
7. ECB makes policy decisions based on aggregate euro area data computed as weighted averages of the data on euro area individual member states. Therefore, in case of small country adopting euro the weighted average of aggregate euro area data do not change considerably.

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Analysis of the Stationarity of East Asian Currencies Using Unit Root Test and Cointegration Test*

Zhiqian Wang†

ABSTRACT

This paper investigates the stationarity of East Asian currencies (ASEAN 6) by using a unit root test and cointegration test. We examine whether the Asian monetary unit (AMU) deviation indicators adjusted by the Balassa–Samuelson effect of ASEAN 6 are stationary over the short term by carrying out a unit root test. We also assess whether cointegration relationships exist over the long term by carrying out a cointegration test. Based on an empirical analysis of 57 combinations, we cannot find any combinations show a significant result. Based on our results, it is clear that exchange rate fluctuations among the East Asian currencies respond to each other asymmetrically and that the issue of exchange rate misalignment needs to be dealt with immediately.

Keywords: Unit Root Test, Cointegration Test, Exchange Rate Misalignment, Intra-Regional Exchange Rate Surveillance

JEL classification codes: F31, F33, F36

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1. Introduction

In 1997, a number of East Asian countries experienced a serious currency crisis. The crisis was blamed on the *de facto* dollar peg exchange rate regime and on double mismatches in currency and the redemption periods. In the aftermath of the Asian currency crisis, the monetary authorities of most East Asian countries came to perceive the importance of establishing an intra-regional exchange rate surveillance system in the East Asian area. In order to realize the establishment of this surveillance system, the Asian monetary unit (AMU), AMU deviation indicator, and AMU deviation indicator adjusted by the Balassa–Samuelson effect (hereafter referred to as the adjusted AMU deviation indicator) have been proposed, along with an intra-regional surveillance process based on these indicators. However, the implications of surveillance will vary depending on whether exchange rate misalignments have a tendency to converge over the long run.

More specifically, based on the need to establish a system for monitoring intra-regional exchange rates and their fluctuations, some policymakers and academics have suggested the introduction of a common basket system in the East Asian area (i.e., Kuroda & Kawai, 2003; Ogawa, 2004; Williamson, 2000). Among the various approaches to simulating a common currency basket, Ogawa and Shimizu (2005, 2006, 2010, 2011) thought that the AMU and the AMU deviation indicator are useful for enhancing intra-regional monetary cooperation. These indicators are expected to strengthen the abilities of a surveillance system, especially in the early detection of exchange rate misalignment. Furthermore, considering the high productivity growth rate in tradable goods sectors and transformations in foreign exchange regimes in some East Asian countries, Ogawa and Wang (2012) calculated the adjusted AMU deviation indicator. It can also identify in what currencies intra-regional exchange rate misalignments occur and how serious they are. However, if exchange rate misalignments occurring in the East Asian currencies involve linear relationships, this means that the currencies' exchange rate fluctuations follow similar trends over the long run and that exchange rate misalignments occurring in the East Asian countries are temporary episodes. Given this, it is necessary to clarify the exchange rate relationships in East Asian currencies when we focus on intra-regional monetary cooperation and exchange rate surveillance. In this paper, we aim to verify whether the East Asian currencies follow a trend of convergence over the long run, by using the adjusted AMU deviation indicators.

The results of our empirical analysis show that the adjusted AMU deviation indicators follow non-stationary processes, as shown by the unit root test. This means

that the adjusted AMU deviation indicators of East Asian currencies do not have the property of mean reversion and that the indicators diverge from each other in the long run. Meanwhile, we also examined whether the adjusted indicators follow a similar trend of fluctuation over the long run by using the error correction model. Of 57 combinations of six ASEAN currencies, 18 combinations have relationships of cointegration. Of these 18 combinations, 16 were rejected in an analysis of the statistical significance of the cointegration vector and the adjustment vector, and the other two were rejected by the consistency of the cointegration vector's sign (positive or negative). Thus, it is obvious that the exchange rates of East Asian countries respond to each other asymmetrically. In order to stabilize the macroeconomic variables of East Asian countries, it is important that exchange rate misalignment be addressed.

This paper is organized as follows. In section 1, we provide an outline of the paper as a whole. In section 2, we review previous studies on the measurements of exchange rate surveillance, which include the AMU, the AMU deviation indicator, and the adjusted AMU deviation indicator. In section 3, we clarify the economic implications of conducting a unit root test and cointegration test on the adjusted AMU deviation indicators. In section 4, we employ data from the adjusted AMU deviation indicators to test the stationarity of six ASEAN currencies through a unit root test, identify the long-term relationships between East Asian currencies through a cointegration test, and, finally, discuss the results of our empirical analysis. In section 5, we discuss the contributions of this paper and directions for future research.

2. AMU, AMU Deviation Indicator and Adjusted AMU Deviation Indicator for Intra-Regional Exchange Rate Surveillance

After the Asian currency crisis of 1997, the monetary authorities of East Asian countries realized the importance of intra-regional monetary cooperation. Unfortunately, the exchange rate fluctuations in East Asian currencies are still asymmetric and some East Asian countries maintain strong interconnecting relationships with the US dollar. Ogawa (2004) pointed out that the exchange rate fluctuations of East Asian currencies could be divided into two groups from the viewpoint of the asymmetric exchange rate response, and that intra-regional exchange rate misalignment was caused by asymmetric exchange rate fluctuations.[1] In order to detect or prevent exchange rate misalignment in its early stages, it is necessary for the monetary authorities of East Asian countries to monitor intra-regional exchange rates. To establish an intra-regional exchange rate surveillance system, the AMU, AMU deviation indicator, and adjusted AMU deviation indicator have been proposed by Ogawa and Shimizu (2005) and Ogawa and Wang

(2012).

2.1 Asian Monetary Unit (AMU)

In the aftermath of the Asian Currency Crisis, policymakers and academics recognized that it is necessary for the monetary authorities of East Asian countries to implement a surveillance system that can monitor intra-regional exchange rates, in order to eliminate exchange rate misalignment. The most effective measurement of surveillance is believed to be the employment of a common currency basket (i.e., Williamson, 1999; Williamson, 2001). With this in mind, Ogawa and Shimizu (2005) devised a new currency basket known as the Asian monetary unit (AMU). The AMU is a currency basket unit that is calculated based on the weighted average of the currencies of ASEAN+3 and follows the same procedures used to calculate the European Currency Unit (ECU). Each currency's weight in the currency basket is based on the share of GDP and trade volume. Because both the United States and the euro area are important trading partners of the East Asian countries, the AMU is denominated based on a weighted average of the US dollar and the euro. A weighted average of the US dollar and the euro vis-à-vis the AMU can be expressed as follows:[2]

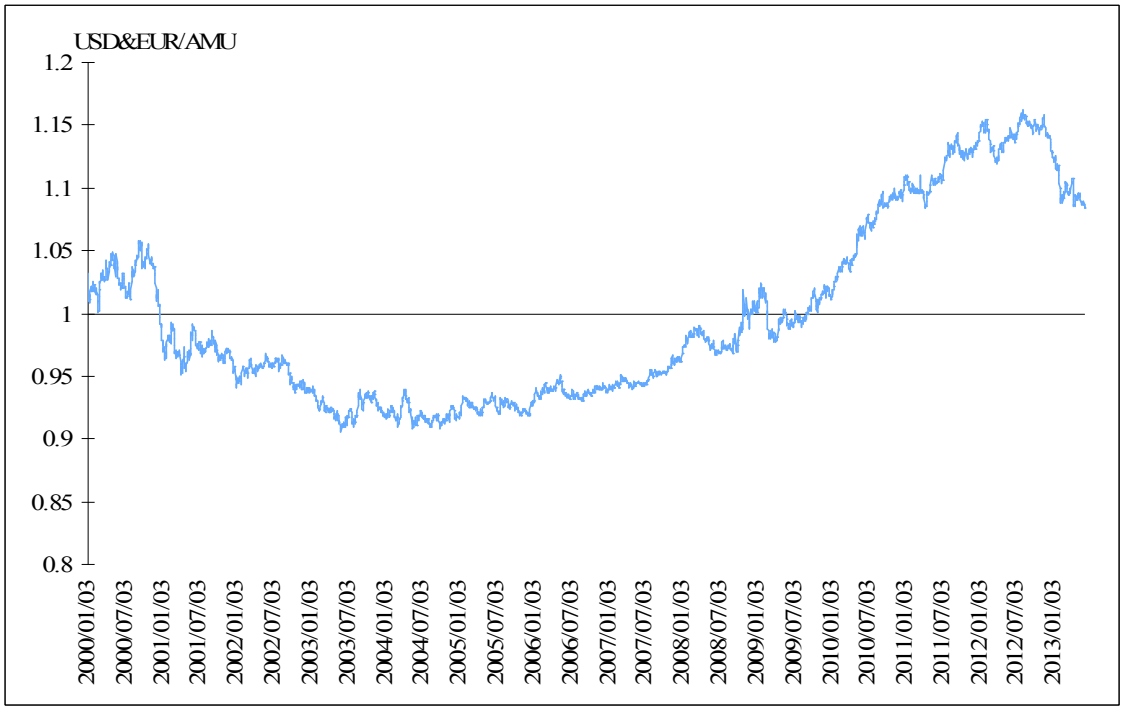
$$\begin{aligned}\frac{USD\,\&\,EUR}{AMU} &= 0.0039\times\frac{USD\,\&\,EUR}{BND}+6.5556\times\frac{USD\,\&\,EUR}{KHR}+3.1592\times\frac{USD\,\&\,EUR}{CNY}\\ &+490.0725\times\frac{USD\,\&\,EUR}{IDR}+25.3757\times\frac{USD\,\&\,EUR}{JPY}+121.6898\times\frac{USD\,\&\,EUR}{KRW}\\ &+10.0825\times\frac{USD\,\&\,EUR}{LAK}+0.1802\times\frac{USD\,\&\,EUR}{MYR}+0.0212\times\frac{USD\,\&\,EUR}{MMK}\\ &+0.9570\times\frac{USD\,\&\,EUR}{PHP}+0.1120\times\frac{USD\,\&\,EUR}{SGD}+1.9481\times\frac{USD\,\&\,EUR}{THB}\\ &+310.3313\times\frac{USD\,\&\,EUR}{VND}\end{aligned} \tag{1}$$

where USD denotes the US dollar, EUR denotes the euro, BND denotes the Brunei dollar, KHR denotes the Cambodian riel, CNY denotes the Chinese yuan, IDR denotes the Indonesian rupiah, JPY denotes the Japanese yen, KRW denotes the Korean won, LAK denotes the Laos kip, MYR denotes the Malaysian ringgit, MMK denotes the Myanmar kyat, PHP denotes the Philippine peso, SGD denotes the Singapore dollar, THB denotes the Thai baht, and VND denotes the Vietnamese dong.

Figure 1 shows the exchange rate of the US dollar and the euro vis-à-vis the AMU from the beginning of 2000 to May of 2013. The AMU was clearly weaker than a weighted average of the US dollar and the euro from late 2000 until the end of 2008. Over that period, many East Asian currencies depreciated against the US dollar and the

euro, due to active capital flows such as the yen carry trade. However, the trend of depreciation appeared to stagnate in the middle of 2005, when the Chinese monetary authority made an announcement regarding the reform of its foreign exchange regime. From the end of 2005, the AMU appreciated against the US dollar and the euro, and followed a significant uptrend of appreciation after the bankruptcy of Lehman Brothers. Some of the euro member countries plunged into a serious debt crisis at the time, and the excessive depreciation of the euro particularly accelerated the appreciation of the AMU.

Figure 1. Exchange Rate of Asian Monetary Unit



Source: RIETI online database.

2.2 AMU Deviation Indicator

In strengthening surveillance over intra-regional exchange rates, the AMU deviation indicator is considered to be useful for monitoring exchange rate misalignments of the East Asian currencies. The AMU deviation indicator is derived from the exchange rate of AMU and a national currency. It is an index for measuring how much an actual exchange rate diverges from the benchmark rate. The AMU deviation indicator is expected to enhance a monetary authority's ability to monitor exchange rate overvaluation or undervaluation, and especially to identify intra-regional exchange rate misalignment.

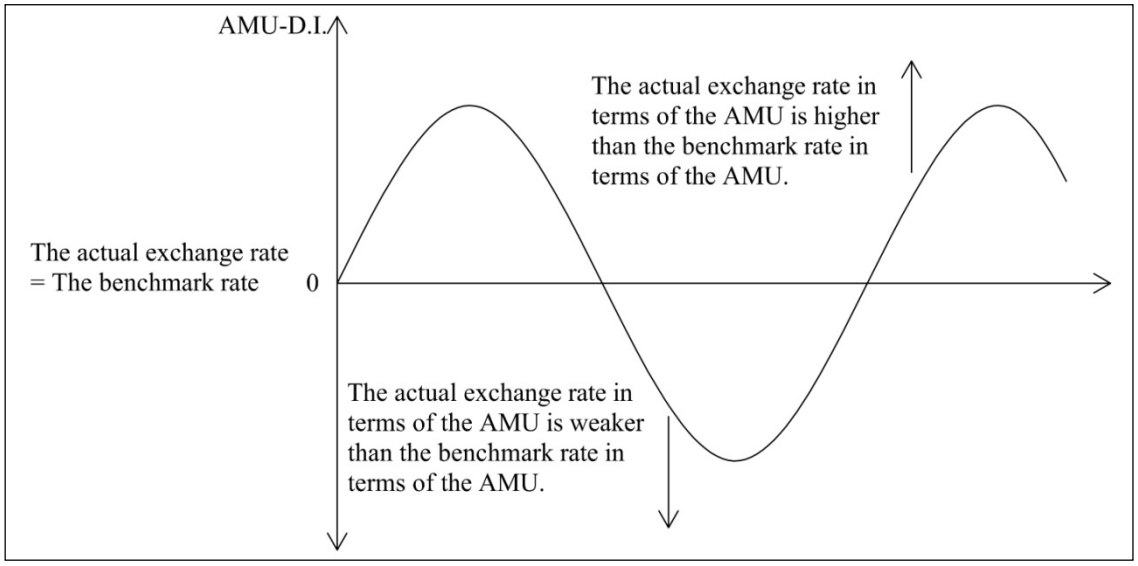
According to the frequency of data updates and the purposes of the surveillance

involved, the AMU deviation indicator can be divided into the nominal AMU deviation indicator, in terms of nominal exchange rate, and the real AMU deviation indicator, by taking into account the inflation rate differential. The nominal AMU deviation indicator represents the differential between an actual exchange rate and the benchmark rate. Therefore, it can be given by the following equation:

$$\textit{The Nominal AMU Deviation Indicator}(\%) = \frac{\left(\frac{AMU}{N.C.}\right)^{Actual} - \left(\frac{AMU}{N.C.}\right)^{Benchmark}}{\left(\frac{AMU}{N.C.}\right)^{Benchmark}} \times 100 \qquad (2)$$

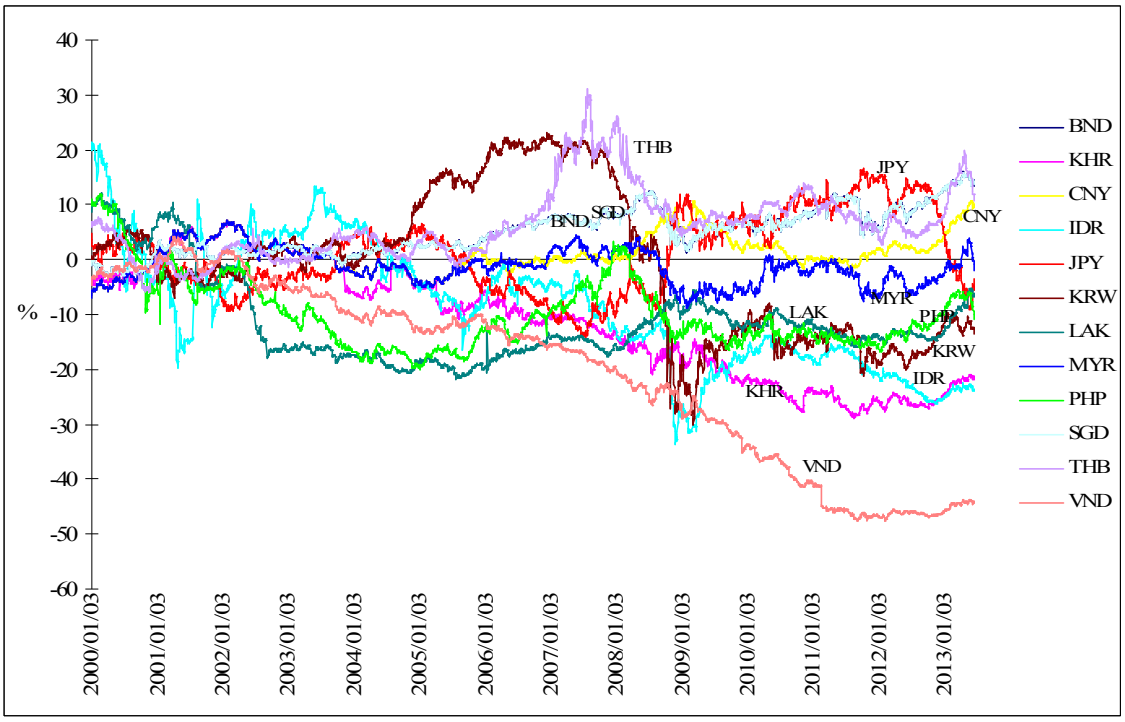
Because the nominal exchange rate, in terms of the AMU vis-à-vis a national currency, can be updated in real time, the nominal AMU deviation indicator is useful for daily real-time exchange rate surveillance. As shown in Figure 2, if the nominal AMU deviation indicator is positive, the exchange rate of the AMU to a national currency is overvalued. If it is negative, the exchange rate of the AMU to a national currency is undervalued. Figure 3 shows the nominal AMU deviation indicator of each currency from the beginning of 2000 to 2013. It clearly shows that fluctuations in the Brunei dollar, the Chinese yuan, the Malaysian ringgit, and the Singapore dollar have been less than 10% in either direction during the whole sample period. Overall, fluctuations in the nominal AMU deviation indicators have increased since around 2005. In particular, after the BNP Paribas shock occurred in the summer of 2007, most East Asian currencies were affected by the substantial depreciation of the euro, and the divergence spread of the nominal AMU deviation indicators between the maximum and the minimum was near to 70%.

Figure 2. Overvaluation or Undervaluation of the AMU Deviation Indicator



Source: RIETI online database.

Figure 3. Nominal AMU Deviation Indicators



Note: The monetary authority of Myanmar officially announced the introduction of floating exchange rate system in April 2012. Nevertheless, the official exchange rates issued by the monetary authority are different from the market rates under the floating exchange rate system. Additionally, Datastream, which is a data source for the AMU, does not yet reflect the market rates for Myanmar. Until Datastream adopts the market rates, Myanmar's AMU deviation indicator will be put on hold. However, as the weight of the Myanmar kyat in the AMU is less than 0.5%, the tentative measurement will not affect the performances of the AMU and the AMU deviation indicators.
Source: RIETI online database.

On the other hand, the real AMU deviation indicator can be calculated by taking into account inflation rate differentials, and can be expressed by the following equation:

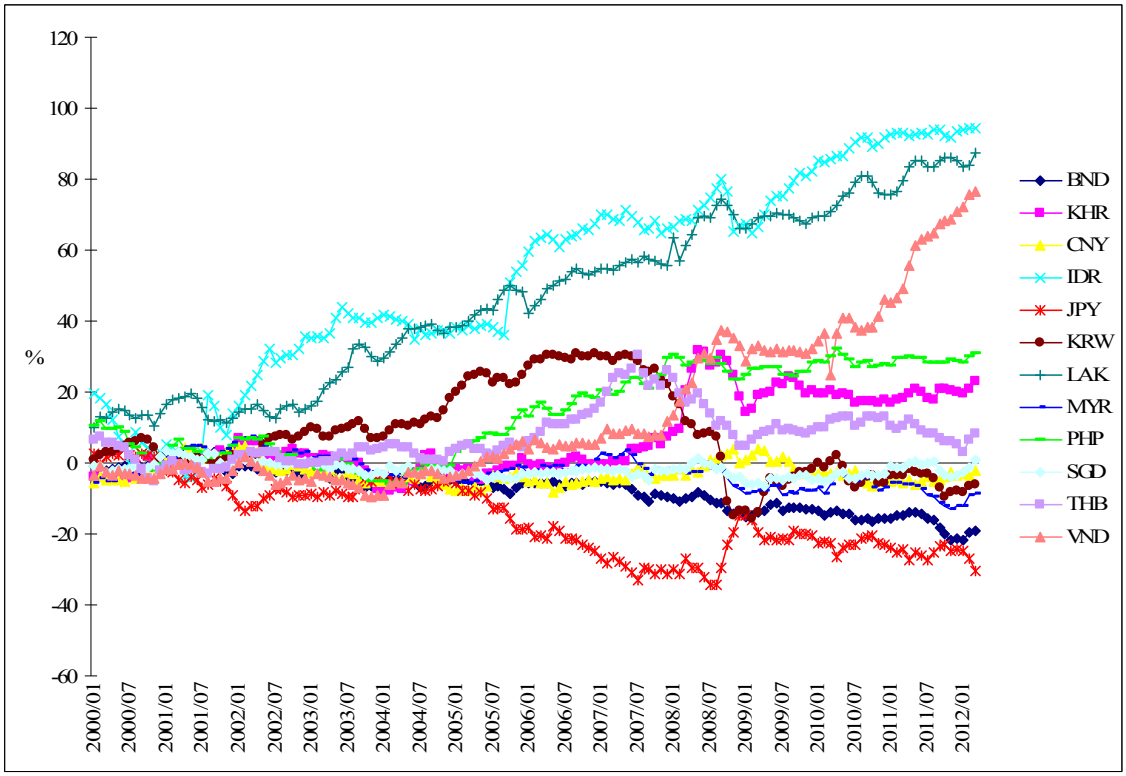
$$\begin{aligned}&\textit{The Rate of Change of Real AMU Deviation Indicator}\ (\%)\\&= \textit{The Rate of Change in Nominal AMU Deviation Indicator of Country "}i\textit{"} - \left(\dot{P}_{AMU} - \dot{P}_i\right)\end{aligned} \tag{3}$$

where $\dot{P}_{AMU}$ is the inflation rate of ASEAN+3 and $\dot{P}_i$ is the inflation rate of country "i".

Due to data constraints, the real AMU deviation indicator can only be calculated monthly, and time lags occur in updating the latest data. The real AMU deviation

indicator is thus more useful when the priority is to focus on exchange rate effects on real economic variables such as trade volume and real GDP. Figure 4 shows the real AMU deviation indicators of the East Asian currencies. It makes it clear that these indicators tend to be overvalued in high-inflation countries such as Indonesia, Laos, and Vietnam. However, they tend to be undervalued in deflationary countries such as Japan. The divergence spread among East Asian currencies has broadened since roughly 2005, and especially in recent years. Since the middle of 2012, the divergence spread between the maximum and the minimum of the real AMU deviation indicators has been near to 120%.

Figure 4. Real AMU Deviation Indicators

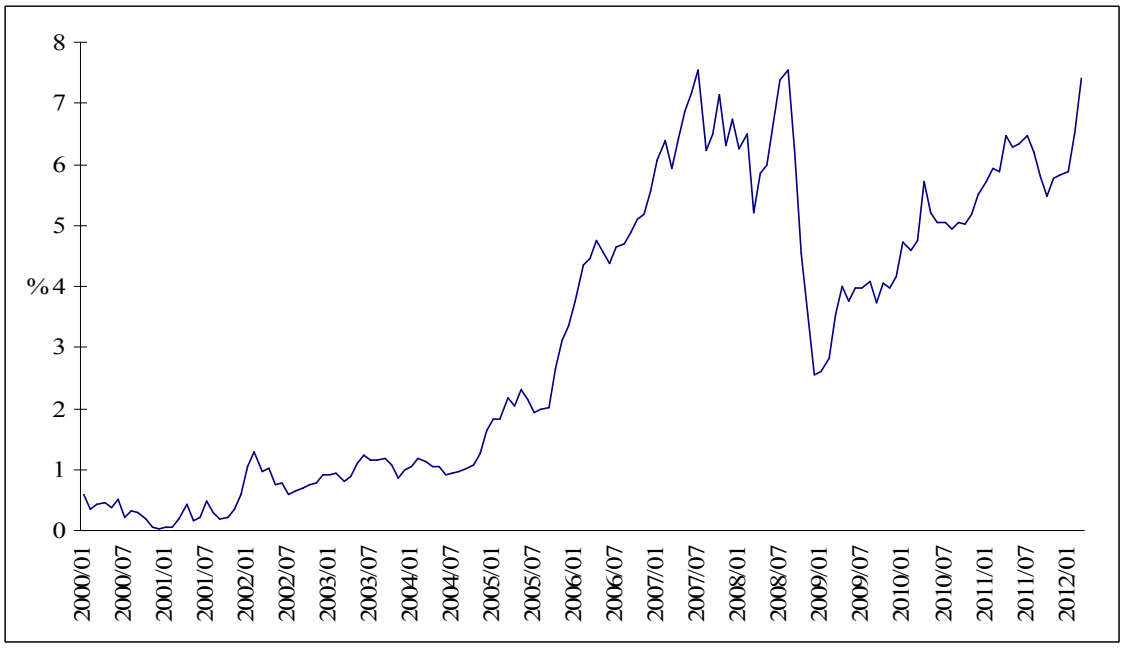


Source: RIETI online database.

Based on the weighted average variance of the real AMU deviation indicators, as shown in Figure 5, it is clear that the weighted average variance of these indicators rose rapidly from the end of 2004 to the summer of 2007.[3] The main reason for this is that the Japanese yen was undervalued by approximately 35% and the Korean won was overvalued by approximately 35% during this period. The asymmetric response of these two currencies has the biggest effect on the fluctuation of weighted average variance. However, the divergence spread between the Japanese yen and the Korean won

decreased since the middle of 2008, which made the weighted average variance of the real AMU deviation indicators decline drastically. After 2009, the weighted average variance of the real AMU deviation indicators showed an upward trend of fluctuation, because the Japanese yen was undervalued by more than 20%, while the other main East Asian currencies remained at a relatively steady level in the same period.

Figure 5. Weighted Average Variance of Real AMU Deviation Indicators



Source: RIETI online database.
Author's calculation.

2.3 AMU Deviation Indicator Adjusted by the Balassa–Samuelson Effect

Ogawa and Wang (2012) employed purchasing power parity (PPP) as a new benchmark rate, and calculated the PPP-based AMU deviation indicator. Due to data constraints, they used consumer price index (CPI) data to calculate the PPP of each East Asian currency. Therefore, the PPP might have been affected by using the data of CPI, which includes the price of non-tradable goods and have tended to diverge from the exchange rate, following the law of one price. In general, the growth rate of productivity in the tradable goods sectors is higher than that in the non-tradable goods sectors. Thus, the rate of inflation in the price of tradable goods tends to be lower than that for non-tradable goods, and the PPP based on the CPI differs from the exchange rate based on the law of one price for tradable goods. The difference between them is known as the Balassa–Samuelson effect.[4] Ogawa and Wang (2012) took the Balassa–Samuelson effect into consideration and adjusted the PPP-based AMU deviation indicator by the

Balassa–Samuelson effect. The adjusted AMU deviation indicator is given by the following equation:

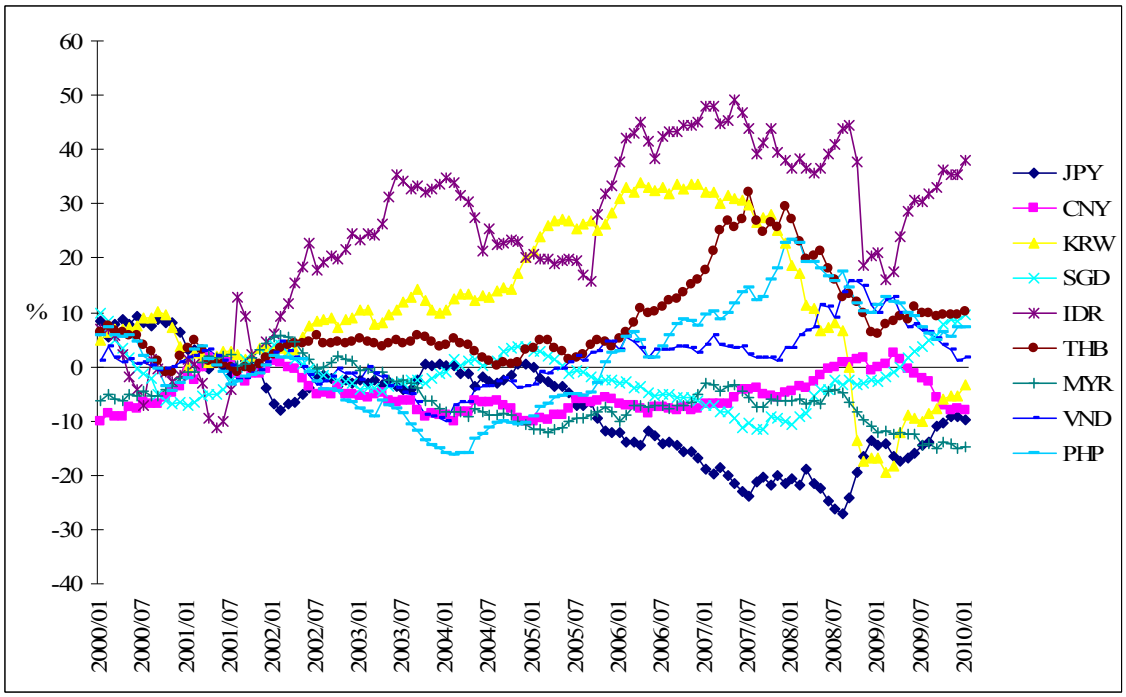
$$\Delta DI^{PPP\ Adjusted\ by\ BS} \approx \Delta DI^{PPP} + \omega_N \cdot (\dot{\alpha}_T - \dot{\alpha}_N) - \omega_N^* \cdot (\dot{\alpha}_T^* - \dot{\alpha}_N^*) \qquad (4)$$

where $\Delta DI^{PPP\ Adjusted\ by\ BS}$ is the rate of change in adjusted AMU deviation indicator, ΔDI^{PPP} is the rate of change in PPP-based AMU deviation indicator, ω_N is the weight of non-tradable goods with regard to the general price level of the domestic economy, $\dot{\alpha}_T$ is the rate of change in productivity in the tradable goods sectors of the domestic economy, $\dot{\alpha}_N$ is the rate of change in productivity in the non-tradable goods sectors of the domestic economy, ω_N^* is the weight of non-tradable goods with regard to the general price level of the foreign economy, $\dot{\alpha}_T^*$ is the rate of change in productivity in the tradable goods sectors of the foreign economy, and $\dot{\alpha}_N^*$ is the rate of change in productivity in the non-tradable goods sectors of the foreign economy.

The adjusted AMU deviation indicator also involves a problem with time lags in updating the latest data, as well as the real AMU deviation indicator. The adjusted AMU deviation indicator is thus more useful in evaluating whether an exchange rate is at an appropriate level, by considering equilibrium exchange rates and the growth rate of productivity.[5] Figure 6 shows the adjusted AMU deviation indicators of ASEAN6+3. There is a tendency for the Japanese yen, the Chinese yuan, and the Malaysian ringgit to be undervalued, while there is a tendency for the Korean won, the Indonesian rupiah, the Thai baht, the Vietnamese dong, and the Philippine peso to be overvalued. The Singapore dollar tends to be balanced over the entire sample period. The divergence spread between the maximum and the minimum was near to 80% after the bankruptcy of Lehman Brothers, and was smaller than the disparity in the real AMU deviation indicators.

By comparing the nominal and real AMU deviation indicators with the adjusted AMU deviation indicator, we found that the adjusted AMU deviation indicator shows a similar trend of fluctuation to the real AMU deviation indicator, but involves different movements from the nominal AMU deviation indicator. For example, in Japan, the Japanese yen was undervalued by approximately 35% in terms of the real AMU deviation indicator in 2008, and was similarly undervalued, by approximately 25%, in terms of the adjusted AMU deviation indicator in the same period. However, focusing on the nominal AMU deviation indicator shows that the Japanese yen has tended to be overvalued since 2008. In China, the Chinese yuan tended to be overvalued, in terms of the nominal AMU deviation indicator, after the bankruptcy of Lehman Brothers, while it was undervalued in terms of both the real and adjusted AMU deviation indicators in the same period.

Figure 6. PPP-based AMU Deviation Indicators Adjusted by the Balassa–Samuelson Effect



Source: RIETI Discussion Paper Series 12-E-078.

In order to stabilize the real effective exchange rate and eliminate failures to cooperate on exchange rate policy, it is necessary for the monetary authorities of East Asian countries to engage in policy coordination. The best means of achieving policy coordination on exchange rates is to implement an exchange rate policy based on a common currency basket. As mentioned above, the AMU and other deviation indicators are useful for engaging in intra-regional monetary cooperation and exchange rate coordination. These indicators are particularly expected to make it easier to detect intra-regional exchange rate misalignments in their early stages. However, the meaning of intra-regional monetary cooperation will vary depending on whether exchange rate fluctuations follow similar trends over the long run. If exchange rate fluctuations can be expressed as having a linear relationship, this means that they will converge with each other and that exchange rate misalignments among currencies will diminish over the long term. Therefore, it is inconceivable that the pricing competitiveness of tradable goods or the trade balance will be aggravated by countries with links to the same cointegration relationships. In other words, if there are cointegration relationships among exchange rate fluctuations, the exchange rate fluctuations will have little impact on the macroeconomic variables relating to exchange rate. Conversely, if the exchange

rate fluctuations cannot be explained by a linear relationship, it will mean that exchange rate misalignments will continue over the long run. In order to eliminate long-term exchange rate misalignments, it will be necessary to engage in intra-regional monetary cooperation. Therefore, clarifying the stationarity and cointegration relationships of East Asian currencies has important implications.

3. Economic Implications of Unit Root Test and Cointegration Test

Generally, fluctuations of macroeconomic variables such as GDP and inflation rate follow time trends, along with economic growth. Until the early 1980s, macroeconomic variables were usually assumed to follow certain trends. After that, with the clarification of non-stationary stochastic process and the introduction of the new concepts of "unit root" and "cointegration," a new approach to time series analysis was established. In this section, we first briefly explain the concepts of "unit root" and "cointegration," and then clarify what their economic implications are by employing two concepts.

3.1 Unit Root and Cointegration

In time series analyses, data are often supposed to follow a stationary process. When a stochastic process satisfies the property of stationarity, it implies that its mean is zero, variance converges to a specific value, and covariance depends on an intertemporal differential. On the other hand, if a stochastic process does not have the property of stationarity, it indicates that its mean, variance, and covariance diverge.[6] Furthermore, with respect to the non-stationary process called random walk, the process's mean is equal to its initial value, and both variance and covariance diverge. When original data series involve random walk and their first-order differences are stationary, random walk is referred to as a unit root process. In a regression model with unit root processes, if error terms follow a non-stationary stochastic process, the regression model is said to involve spurious regression. However, if the error terms follow a stationary stochastic process, the original data series are thought to have a relationship of cointegration. Non-stationary stochastic processes are cointegrated over the long run, which also means that they interact with each other, and that there are long-term equilibrium relationships among the original data series.

3.2 Economic Implications of Unit Root Test and Cointegration Test on the Adjusted AMU Deviation Indicators

By testing whether the adjusted AMU deviation indicators follow unit root processes, we can clarify the properties of the adjusted AMU deviation indicators.[7] If

the null hypothesis that the adjusted AMU deviation indicators follow unit root processes is rejected, it means that any divergence that is currently occurring is temporary, and will vanish over the long run. On the other hand, if the null hypothesis cannot be rejected, it means that the adjusted AMU deviation indicators are affected by factors that will make divergence continue over the long run. One factor can be a structural problem with the foreign exchange regime. As the AMU is a currency basket, the exchange rate of each currency, in terms of the AMU, also reflects a relationship of the home currency with the weighted average of the whole area. Unless each country adopts the same or a similar foreign exchange regime, the exchange rate fluctuations of East Asian currencies will differ from each other.

On the other hand, if the adjusted AMU deviation indicators follow unit root processes, it is necessary to examine whether there cointegration relationships exist among the non-stationary processes. The reason for this is that fluctuations in the adjusted AMU deviation indicators may be related to each other over the long term. If the adjusted AMU deviation indicators are confirmed to converge over the long run, it means that the exchange rate fluctuations of these currencies can be explained by a linear relationship. In other words, exchange rate misalignments happening over the short term will converge with each other over the long term.

Although a linear relationship implies that there are cointegration relationships among the adjusted AMU deviation indicators, the meaning of cointegration differs based on the significance of the cointegration vector and the adjustment vector. In other words, a cointegration relationship cannot be accepted unless the test statistics of the cointegration vector and the adjustment vector are statistically significant. Furthermore, the signs of the cointegration and adjustment vectors are also important factors in the interpretation of the meaning of cointegration. If the test statistics of the cointegration and adjustment vectors are statistically significant, the exchange rate fluctuations will not converge unless the signs of the vectors are consistent. In other words, short-term exchange rate misalignments converge over the long run only if the test statistics of the two vectors are statistically significant and the sign of the vectors fulfills the requirement of consistency. Therefore, we can identify whether the exchange rate fluctuations of East Asian currencies will converge over the long run by performing a cointegration test. Monetary cooperation should occur among countries whose currencies were involved in exchange rate misalignments.

4. Empirical Analysis

4.1 Data and Sample Period

As mentioned above, we employ the adjusted AMU deviation indicator to analyze to the stationarity of East Asian currencies.[8] The calculation of the adjusted AMU deviation indicator is as follows. First, the PPP-based AMU deviation indicator is calculated by using the AMU and the price level of each country.[9] Secondly, the Balassa–Samuelson effect of each currency is calculated. Finally, the adjusted AMU deviation indicator is calculated by referring to the PPP-based AMU deviation indicator and the Balassa–Samuelson effect.[10]

The sample period is from January 2000 to August 2008, just before the bankruptcy of Lehman Brothers.[11]

4.2 Methodology

We identify whether divergence between the actual exchange rates and the benchmark exchange rates will continue over the long run based on a unit root test, using the adjusted AMU deviation indicator. The unit root test and test statistics are based on Dickey and Fuller (1979), under the assumption that the adjusted AMU deviation indicator follows the $AR(p)$ process, and the $AR(p)$ process is as follows:

$$DI_t = \rho_1 DI_{t-1} + \rho_2 DI_{t-2} + \rho_3 DI_{t-3} + \cdots + \rho_p DI_{t-p} + u_t,\ u_t \sim iid\left(0, \sigma^2\right) \qquad (5)$$

The null and alternative hypotheses based on the augmented Dickey–Fuller test are as follows:[12]

$$H_0 \ : \ |\psi| = 1 \quad vs. \quad H_1 \ : \ |\psi| < 1 \qquad (6)$$

where $\psi = \rho_1 + \rho_2 + \rho_3 + \cdots + \rho_p$.

The null hypothesis indicates that the stochastic process follows a unit root process and that the data series are non-stationary, while the alternative hypothesis indicates that the stochastic process does not follow a unit root process and that the data series are stationary.[13] According to the unit root test, if the adjusted AMU deviation indicator follows a unit root process, this implies that divergence will continue over the long run.

When the adjusted AMU deviation indicators follow unit root processes, it is necessary to identify whether cointegration relationships exist over the long run. In this case, a cointegration test can be employed to determine cointegration relationships. The error correction model that is used in the cointegration test is as follows:

$$\Delta DI_t = \sum_{k=1}^{p-1} \Gamma_k \Delta DI_{t-k} + \Pi DI_{t-1} + \varepsilon_t \qquad (7)$$

where $\Pi = \alpha\beta'$, α is a matrix in terms of adjustment vectors, β' is a matrix in terms

of cointegration vectors, DI_{t-1} is a $n \times 1$ vector, and $DI_{t-1} = \left(DI_{1,t-1}, DI_{2,t-1}, \cdots, DI_{n,t-1}\right)'$.

On the other hand, the number of cointegration relationships will change according to lag order. It is therefore important to choose an appropriate lag order, in order to identify the number of cointegration relationships. We assume that each stochastic process is affected by the previous shocks and that the shocks last one year. Under these assumptions, the selection of lag order will begin with two, and the order will increase gradually, with the best order selected from 12 final possibilities. We base our criteria for choosing a lag order on Ljung–Box test statistics and Lagrange multiplier test statistics. We select a lag order without serial correlation but with cointegration relationships. If there are two or more lag orders that fulfill the criteria of selection, we also consider other benchmarks, based on the information criteria. With respect to the information criteria, the Akaike information criteria (AIC) and the Schwartz Bayes information criteria (SBIC) can be effectively used, but it is not always appropriate to choose the same model based on the two information criteria. We thus employ SBIC on the basis of the work of Juselius (2006). We also employ Hannan and Quinn (HQ) statistics because of our sample size.[14]

Furthermore, in order to determine the characteristics of each data series in the cointegration system, we conduct three additional Chi-square tests on the cointegration vector and the adjustment vector. The null hypotheses of the three additional Chi-square tests are as follows:

(a) Any data series do not include in the long-term equilibrium relationships. In other words, although the data series are included in the cointegration system, the test statistics are not statistically significant over the long run.

(b) Any data series that are included in the cointegration system satisfy the property of stationarity, but the property of stationarity does not relate to other cointegration vectors.

(c) Any data series that are included in the cointegration system have the property of weak exogeneity over the long run.

The additional tests (a) and (c) are useful for identifying a cointegration relationship. Because the number of cointegration relationships varies depending on lag order, there is a possibility of over-identification or under-identification in selecting a model. However, the risk of erroneous identification in model selection can be reduced by testing the relationships of data series over the long run, as well as data series exogeneity. On the other hand, the additional test (b) can identify whether error correction mechanisms are based on exogenous factors such as individual effects on

error terms. In order to clarify the characteristics of exchange rate misalignments among East Asian currencies, it is necessary to focus on the combinations in which the adjusted AMU deviation indicators have strong correlationships. We aim to identify the relationships between exchange rate fluctuations, and thus, expect the cointegration system to develop the stationarity of data series. Therefore, it is important to use three additional tests to identify these relationships.

4.3 Empirical Analysis Results

Tables 1 and 2 show the results of a unit root test of each country's adjusted AMU deviation indicator. The null hypothesis stating that the adjusted AMU deviation indicator follows a unit root process cannot be rejected. It is thus clear that the adjusted AMU deviation indicator of each country is non-stationary. Therefore, the candidates for a test of cointegration relationships combine two currencies at least and six currencies at most, and the total number of combinations is 57.

Since the error term of the error correction model does not allow for serial correlations, we checked the properties of each combination's error term. Out of 57 combinations, 18 were considered not to involve serial correlation. We thus focused on the 18 combinations and conducted three additional tests under the alternative hypotheses that each data series is included in the long equilibrium relationships, that the stationarity of each data series is significantly relevant to cointegration vectors, and that each data series does not have the property of weak exogeneity.[15] The test results are summarized in Table 3. For example, with respect to Singapore, there are 13 combinations that are cointegrated over the long run. Of these, 13 out of 13 are significantly included in a long-term relationship, while in 11 out of 13, stationarity is significantly relevant to cointegration vectors, and in 12 out of 13, the data series do not have the property of weak exogeneity.

With respect to the whole East Asian area, most of the combinations without serial correlations involve the Singapore dollar. Out of 18 combinations, 13 were found to have this tendency, the reason for which could be the currency basket regime adopted by the monetary authority of Singapore. On the other hand, in focusing on the currencies of the whole area, combinations based on the Singapore dollar and the Indonesian rupiah as well as the Singapore dollar and the Thai baht show that the Singapore dollar, the Indonesian rupiah, and the Thai baht have the tendency to cointegrate. This is because Indonesia is the second-largest economy in the region, Thailand maintains its economic growth rate at roughly 6%, and both of these countries are important trading partners of Singapore. As such, the monetary authority of

Singapore is conscious of the two currencies and takes both them into consideration in its decisions on basket currencies.

Table 1. Unit Root Test (with intercept)

Unit Root Test (ADF)								
Currency	Test Statistics		Currency	Test Statistics		Currency	Test Statistics	
	Level	1st Diff.		Level	1st Diff.		Level	1st Diff.
SGD	-2.81*	-6.97***	THB	-1.20	-7.64***	VND	-0.10	-9.31***
IDR	-0.97	-8.36***	MYR	-1.40	-7.99***	PHP	-0.71	-6.60***
Unit Root Test (PP)								
Currency	Test Statistics		Currency	Test Statistics		Currency	Test Statistics	
	Level	1st Diff.		Level	1st Diff.		Level	1st Diff.
SGD	-3.18**	-7.08***	THB	-1.10	-7.67***	VND	-0.44	-9.49***
IDR	-0.98	-8.22***	MYR	-1.39	-8.01***	PHP	-0.30	-6.56***
Unit Root Test (KPSS)								
Currency	Test Statistics		Currency	Test Statistics		Currency	Test Statistics	
	Level	1st Diff.		Level	1st Diff.		Level	1st Diff.
SGD	0.47**	0.16	THB	0.70**	0.15	VND	0.48**	0.28
IDR	1.00***	0.07	MYR	0.51**	0.16	PHP	0.52**	0.53**

Note: SGD denotes the Singapore dollar, IDR denotes the Indonesian rupiah, THB denotes the Thai baht, MYR denotes the Malaysian ringgit, VND denotes the Vietnamese dong, and PHP denotes the Philippine peso.

*** denotes significance at the 1% level.

** denotes significance at the 5% level.

* denotes significance at the 10% level.

Source: RIETI Discussion Paper Series 12-E-078.

Author's calculation.

Table 2. Unit Root Test (with linear trend and intercept)

Unit Root Test (ADF)								
Currency	Test Statistics		Currency	Test Statistics		Currency	Test Statistics	
	Level	1st Diff.		Level	1st Diff.		Level	1st Diff.
SGD	-2.61	-7.05***	THB	-2.13	-7.61***	VND	-0.87	-9.66***
IDR	-2.73	-8.32***	MYR	-1.69	-7.95***	PHP	-1.83	-6.93***
Unit Root Test (PP)								
Currency	Test Statistics		Currency	Test Statistics		Currency	Test Statistics	
	Level	1st Diff.		Level	1st Diff.		Level	1st Diff.
SGD	-3.03	-7.19***	THB	-1.91	-7.64***	VND	-1.06	-9.73***
IDR	-2.46	-8.17***	MYR	-1.75	-7.97***	PHP	-1.44	-6.54***
Unit Root Test (KPSS)								
Currency	Test Statistics		Currency	Test Statistics		Currency	Test Statistics	
	Level	1st Diff.		Level	1st Diff.		Level	1st Diff.
SGD	0.12*	0.10	THB	0.21**	0.13*	VND	0.24***	0.06
IDR	0.10	0.07	MYR	0.15**	0.16**	PHP	0.30***	0.06

Note: SGD denotes the Singapore dollar, IDR denotes the Indonesian rupiah, THB denotes the Thai baht, MYR denotes the Malaysian ringgit, VND denotes the Vietnamese dong, and PHP denotes the Philippine peso.

*** denotes significance at the 1% level.

** denotes significance at the 5% level.

* denotes significance at the 10% level.

Source: RIETI Discussion Paper Series 12-E-078.

Author's calculation.

Table 3. Additional Test Results

	Additional Test (a)	Additional Test (b)	Additional Test (c)
Singapore	13(13)	11(13)	12(13)
Indonesia	6(12)	12(12)	5(12)
Thailand	6(7)	7(7)	3(7)
Malaysia	3(7)	7(7)	3(7)
Vietnam	9(12)	11(12)	5(12)
The Philippines	5(7)	6(7)	3(7)

Note: The last three columns represent how many null hypotheses are rejected in additional tests (a), (b), and (c). The number of cointegration relationships is shown in parentheses.
Source: RIETI Discussion Paper Series 12-E-078.
Author's calculation.

Furthermore, the combinations for which the three additional tests are simultaneously significant are the Indonesian rupiah and the Vietnamese dong, and the Singapore dollar, the Indonesian rupiah and the Philippine peso. The error correction models of the two combinations can be expressed as follows.

With respect to the Indonesian rupiah and the Vietnamese dong, the error correction model can be expressed by the following linear combination:

$$\begin{pmatrix} \Delta IDR \\ \Delta VND \end{pmatrix} = \sum_{k=1}^{2-1} \Gamma_k \begin{pmatrix} \Delta IDR \\ \Delta VND \end{pmatrix}_{t-k} + \begin{pmatrix} -0.75 \\ -0.47 \end{pmatrix} \begin{pmatrix} 0.13 & 0.13 \end{pmatrix} \begin{pmatrix} IDR \\ VND \end{pmatrix}_{t-1} + \begin{pmatrix} \varepsilon_{IDR} \\ \varepsilon_{VND} \end{pmatrix}_t \qquad (8)$$

where IDR denotes the Indonesian rupiah and VND denotes the Vietnamese dong.

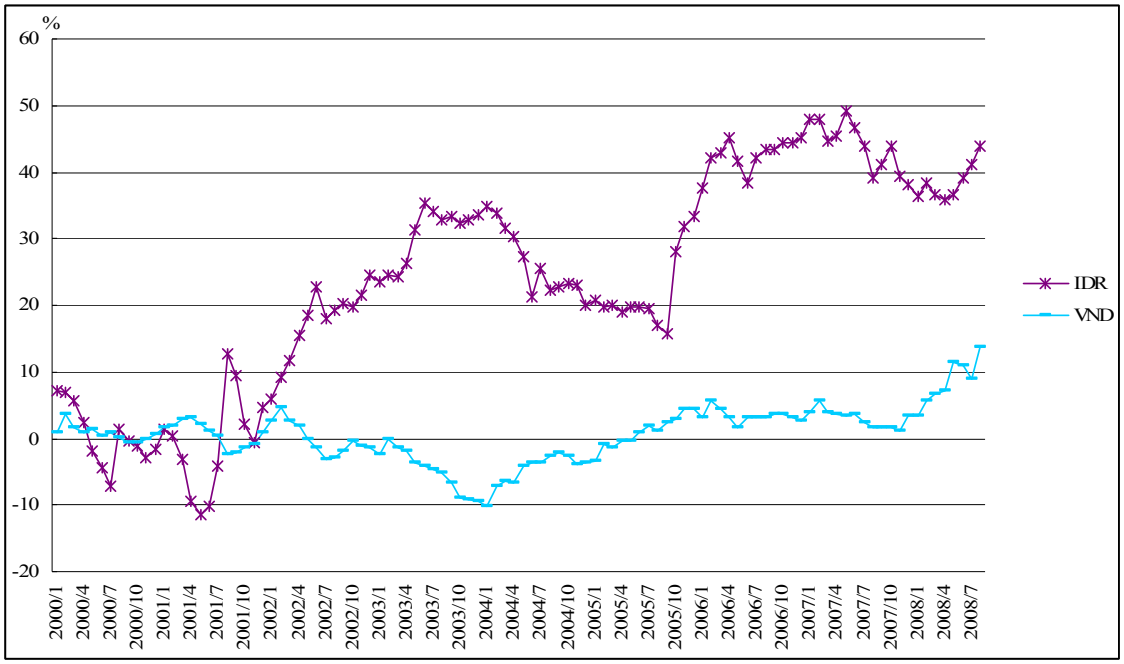
The linear combination of the two currencies over the long run can be expressed as follows:

$$IDR = -1.01VND + u_{IDR} \qquad (9)$$

As the sign of combination of the Indonesian rupiah and the Vietnamese dong is negative, the adjusted AMU deviation indicators of the two currencies follow an adverse long-term trend of fluctuation, which means that the exchange rate misalignments of the two currencies do not converge over the long run. This can be explained by the fluctuations of the nominal AMU deviation indicator, as well as the inflation rate. The nominal AMU deviation indicator of the Indonesian rupiah tended to be slightly undervalued or balanced during the whole sample period, while at the same time, Indonesia was experiencing a high inflation rate. Therefore, the adjusted AMU deviation indicator that is calculated with the PPP-based AMU deviation indicator and the Balassa–Samuelson effect has a tendency toward overvaluation. On the other hand,

the nominal AMU deviation indicator of the Vietnamese dong tended to be undervalued during the whole sample period, while the inflation rate in Vietnam was consistently high. The adjusted AMU deviation indicator of the Vietnamese dong thus tended to be balanced or slightly undervalued. For these reasons, the two currencies are following an adverse trend of fluctuation. Figure 7 makes it clear that the Indonesian rupiah and the Vietnamese dong fluctuated in opposite directions.

Figure 7. Adjusted AMU Deviation Indicators (Indonesian rupiah and Vietnamese dong)



Note: IDR denotes the Indonesian rupiah and VND denotes the Vietnamese dong.

Source: RIETI Discussion Paper Series 12-E-078.

With respect to the Singapore dollar, the Indonesian rupiah and the Philippine peso the error correction model can be expressed by the following linear combination:

$$\begin{pmatrix} \Delta SGD \\ \Delta IDR \\ \Delta PHP \end{pmatrix} = \sum_{k=1}^{8-1} \Gamma_k \begin{pmatrix} \Delta SGD \\ \Delta IDR \\ \Delta PHP \end{pmatrix}_{t-k} + \begin{pmatrix} 0.49 \\ 0.62 \\ 0.39 \end{pmatrix} \begin{pmatrix} -0.56 & -0.15 & -0.18 \end{pmatrix} \begin{pmatrix} SGD \\ IDR \\ PHP \end{pmatrix}_{t-1} + \begin{pmatrix} \varepsilon_{SGD} \\ \varepsilon_{IDR} \\ \varepsilon_{PHP} \end{pmatrix}_t \qquad (10)$$

where SGD denotes the Singapore dollar, IDR denotes the Indonesian rupiah and PHP denotes the Philippine peso.

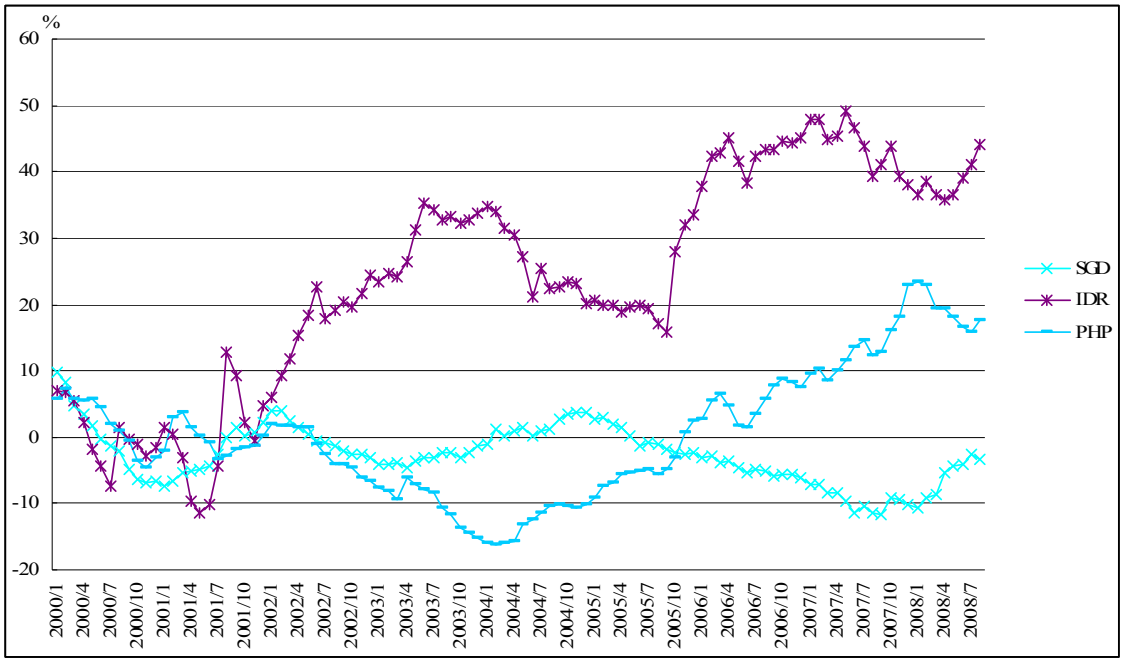
The linear combination of the three currencies over the long run can thus be expressed as follows:

$$SGD = -0.27IDR - 0.32PHP + u_{SGD} \qquad (11)$$

As the sign of combination of the Singapore dollar, the Indonesian rupiah and the Philippine peso is negative, the adjusted AMU deviation indicators of the three

currencies follow an adverse long-term trend of fluctuation, which means that the exchange rate misalignments of the three currencies do not converge over the long run. The negative correlationship among the Singapore dollar, the Indonesian rupiah and the Philippine peso is relevant to the foreign exchange regime adopted by the monetary authority of Singapore and a high inflation rate occurred in Indonesia and the Philippines. As Singapore's monetary authority pays attention to the exchange rate of its main trading partners, and tries to stabilize the Singapore dollar with them, which is why the exchange rates of the Singapore dollar fluctuate at stable level. On the other hand, the other two countries, Indonesia and the Philippines, were suffering from a high inflation rate. It is obvious that the adjusted AMU deviation indicators of the Indonesian rupiah and the Philippine peso had a tendency of overvaluation. From Figure 8, it is clear that the Singapore dollar, the Indonesian rupiah and the Philippine peso do not converge.

Figure 8. Adjusted AMU Deviation Indicators (Singapore dollar, Indonesian rupiah and Philippine peso)



Note: SGD denotes the Singapore dollar, IDR denotes the Indonesian rupiah and PHP denotes the Philippine peso.

Source: RIETI Discussion Paper Series 12-E-078.

Hence, we cannot find any combinations for which there is no serial correlation in error terms and the three additional Chi-square tests are significant simultaneously.[16]

5. Conclusion

In this paper, we reviewed advanced studies of measurements that could be used to engage in monetary cooperation in the East Asian area. We then investigated the stationarity of East Asian currencies by using the adjusted AMU deviation indicators.

Since the nominal AMU deviation indicators can be calculated on a daily basis, they are useful for real-time surveillance. In contrast, the real AMU deviation indicators and adjusted AMU deviation indicators can be calculated only on a monthly basis and involve time lags in data release. For these reasons, they cannot be applied to monitor exchange rate fluctuations. However, in cases where the priority is to focus on exchange rate effects on real economic variables, such as GDP and trade balance, the real AMU deviation indicators and adjusted AMU deviation indicators are more useful.

On the other hand, based on the results of a unit root test, we found that the adjusted AMU deviation indicators do not have the property of mean reversion. In other words, divergence from the benchmark rate is not a temporary episode but continues over the long run. In order to identify whether long-term cointegration relationships exist, we also employed the error correction model to run a cointegration test. By focusing on combinations composed of at least two and at most six currencies, we found that 18 out of 57 combinations had cointegration relationships. Most of these cointegration relationships were rejected based on their lack of statistical significance, as was shown by the results of three additional tests. The exceptions were the combinations of the Indonesian rupiah and the Vietnamese dong and of the Singapore dollar, the Indonesian rupiah and the Philippine peso. As the sign of the linear combination of the two combinations were negative, both of them could not be accepted for long-run cointegration. Therefore, we cannot find any currencies of which their linear combination is statistically significant. The results of this empirical analysis correspond to the foreign exchange regimes adopted by East Asian countries. Since most East Asian countries follow their own foreign exchange policies, exchange rate fluctuations lack synchronization and exchange rate misalignments do not converge over the long run.

According to the results of our cointegration test, it is clear that the exchange rate fluctuations of East Asian countries are asymmetric. As intra-regional trade is expanding, it is important to detect the asymmetric responses of exchange rates in the early stages in order to stabilize trade balance. We expect that the AMU deviation indicators and the adjusted AMU deviation indicators will be used to monitor intra-regional exchange rates and macroeconomic variables related to exchange rates, and that they can contribute to construct a monetary cooperation system in the East

Asian area. In a future study, we intend to conduct a non-linear approach on cointegration relationship and extend sample period along with data accumulation.

Furthermore, the trilemma of international finance indicates that we have to abandon the liberalization of capital flow or the independence of monetary policy if we hope to stabilize exchange rates. Given the current circumstances of East Asia, it would be difficult to restrict the convertibility of capital accounts through capital control or foreign exchange intervention, and abandoning independent monetary policy would also be unrealistic. One means of solving the problems of the trilemma is to employ a mixed policy based on the combination of monetary and foreign exchange policies under a liberalized capital flow (Ito & Hayashi, 2006). By focusing on mixed policy, monetary authorities could carry out their own monetary policies by setting inflation targets, while, at the same time, adjusting exchange rates by referring to a currency basket. An inflation target could stabilize international capital flow, and foreign exchange policy could indirectly affect inflation rates as a result of pass-through effects. Monetary policy and foreign exchange policy have a complementary relationship in mixed policy. Therefore, policy coordination based on a combination of monetary policy and foreign exchange policy would be suitable to the conditions in the East Asian area.

It has been more than 10 years since the idea of a common currency basket has been considered in East Asia; some nations are not interested in it, and the debate on its introduction and use continues. However, the ability to respond to financial crises is a critical one, and given how a common currency basket can enhance this capacity, now is the time to spark greater interest in the currency basket within the area of East Asia. Doing so is a matter of emphasizing not only one's own national interests, but also those of the entire East Asian region.

NOTES

1. In Ogawa (2004), the East Asian currencies include the Singapore dollar, the Indonesian rupiah, the Thai baht, the Malaysian ringgit, the Philippine peso, the Chinese yuan, the Korean won, the Hong Kong dollar, and the Taiwanese dollar.
2. The share and weight of each country is based on the 8th version of the AMU. See the AMU website for more detail, at http://www.rieti.go.jp/users/amu/en/index.html.
3. The weighted average variance of the real AMU deviation indicators is calculated based on the weight of each currency in the AMU, as well as the real AMU deviation indicators.
4. As Kohler (2000) mentioned, differences in productivity growth (tradable and nontradable goods sectors) could affect an overall inflation. In the cases of Japan and Germany, both of the two countries showed a trend of tradable goods sectors growth in the 1960s and 1970s. It also shows that there is a dominance of nontradable sectors growth in some developed and developing countries in recent growth trends. With respect to the East Asian area, most of the countries have experienced a growth that is led by productivity growth in the tradable goods sectors (Ogawa & Wang, 2012; Ogawa & Wang, 2013a). The growth patterns of East Asian countries are similar to the growth of Japan and Germany. I am indebted to the anonymous referee for comments on the Balassa–Samuelson effect between European Monetary Union and East Asian area.
5. Since the economic growth model of each country in East Asian area is different, the classification of tradable and non-tradable goods sectors could cause a bias in the growth rates of productivity. Specifically, the growth rates of productivity in the tradable goods sector are affected by technical progress and capital–labor intensity. However, in order to evaluate the exchange rate level and identify the exchange rate misalignments among the East Asian currencies appropriately, it is necessary to keep the benchmark rate at an appropriate level. In a future study, what is needed is to estimate the growth rates of productivity using some new model (for example, by using the Cobb–Douglas production function for calculation), and also introduce some other conceptions of equilibrium exchange rate into studies on the adjusted AMU deviation indicator.
6. Here "the stochastic process's mean, variance, and covariance diverge" implies that the stochastic process's mean does not have the property of mean reversion, and that both variance and covariance are dispersing over time. For example, in an $AR(1)$ process as $y_{i,t} = \alpha_i + \beta_i y_{i,t-1} + \varepsilon_{i,t}$, $\varepsilon_{i,t} \sim W.N.(0, \sigma^2)$, the stochastic process's mean, variance, and covariance can be expressed by $E(y_{i,t}) = \beta_i^t y_0$, $\mathrm{var}(y_{i,t}) = \sigma^2 \sum_{l=0}^{t-1} \beta_i^{2l}$, and $\mathrm{cov}(y_{i,t}, y_{i,t-s}) = \beta_i^s \sigma^2 \sum_{l=0}^{t-s-1} \beta_i^{2l}$, respectively. If the stochastic process does not satisfy the property of stationarity, which is $|\beta_i| > 1 \,\&\, t \to \infty$, then the stochastic process's mean, variance, and covariance depend on time t.
7. In order to examine the long-term relationships in the East Asian currencies, we focus on the exchange rate misalignments occurring among the currencies, and employ the adjusted AMU deviation indicators to identify the relationships. The reason for this is as follows. The adjusted AMU deviation indicator, in which the benchmark rate is time-varying, can especially dynamically reflect real economic fundamentals. It also takes into account the Balassa–Samuelson effect, and thus exchange rate misalignments

occurring in the East Asian countries can be caught more accurately. Through preventing or narrowing exchange rate misalignments among the East Asian countries, macroeconomic variables such as trade balance and capital flow can be stabilized. Therefore, we use the adjusted AMU deviation indicator as a reference identifying the long-term exchange rate relationships in the East Asian currencies.

8. East Asian currencies consist of the Singapore dollar, the Indonesian rupiah, the Thai baht, the Malaysian ringgit, the Philippine peso and the Vietnamese dong. As mentioned in Ogawa and Kawasaki (2003), some of East Asian currencies are satisfied with the condition of creating a common currency basket, we therefore focus on the most likely candidates, which their currencies are expected to be included in the common currency basket.

9. Due to data constraints, the CPIs are employed as price levels.

10. For more detail, see Ogawa and Wang (2012).

11. The sample period continues until just before the bankruptcy of Lehman Brothers because notable changes in exchange rate fluctuation occurred before and after the bankruptcy. More specifically, although the benchmark exchange rate of the adjusted AMU deviation indicator is given by referring to the fundamental of real economy, and is thought of as robustness, we also need to pay attention to actual exchange rates when we focus on the movement of the adjusted AMU deviation indicator, because the adjusted AMU deviation indicator is calculated with the actual exchange rate as well as the benchmark exchange rate. It is interesting to note how the adjusted AMU deviation indicator fluctuated after the bankruptcy of Lehman Brothers. In our future research, we plan to carry out an additional analysis of the sample period after the bankruptcy of Lehman Brothers, along with the accumulated data.

12. For more detail, see Hamilton (1994).

13. As an additional means of evaluation, we also employ the Phillips–Perron (PP) test. The test statistics are based on Phillips and Perron (1988). The PP test relaxes the limitations of the assumptions of the ADF test, and takes into account the auto-regression of error terms, as well as the heterogeneity of variance. The null hypothesis of the PP test is that the stochastic process follows a unit root process, while the alternative hypothesis is that the stochastic process does not follow a unit root process. On the other hand, it is known that the ADF has low power against stable auto-regressive alternatives with roots near unity. Here we also employ the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test. The test statistics are based on Kwiatkowski, Phillips, Schmidt and Shin (1992). The KPSS test also relaxes the limitations of the assumptions of the ADF test, and takes into account the auto-correlation of error terms. The null hypothesis of the KPSS test is that the stochastic process is stationary, while the alternative hypothesis is that the stochastic process follows a unit root process.

14. For more detail, see Shittu and Asemota (2009) for a comparison between the test statistics of SBIC and HQ.

15. See Appendix for test results.

16. We also check the stationarity of each combination from the aspect of panel unit root test, but we cannot find any combinations are statistically significant. The results of panel unit root test are not reported because of space limitations but are available upon request.

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Appendix 1(1). Chi-Square Tests

Combination		SGD	IDR	THB	MYR	VND	PHP	Combination		SGD	IDR	THB	MYR	VND	PHP
SGD IDR	P=10	5.66**	0.24					SGD IDR VND	P=6	13.57***	3.46*			10.94***	
	R=1*	0.24	5.66**						R=1**	11.84***	16.92***			18.94***	
		5.25**	0.24							14.24***	1.49			0.82	
SGD THB	P=6	12.70***		5.57**				SGD IDR PHP	P=8	27.89***	17.20***				26.37***
	R=1***	5.57**		12.70***					R=1***	27.02***	30.55***				37.15***
		12.39***		2.25						24.90***	3.45*				6.70***
SGD VND	P=7	19.25***				5.06**		SGD MYR VND	P=6	6.26***			3.40*	1.16	
	R=1**	5.06**				19.25***			R=1**	3.72			17.35***	11.74***	
		17.54***				0.68				4.99**			2.87*	0.01	
IDR VND	P=2		15.09***			3.43*		SGD VND PHP	P=6	8.64***				1.08	3.50*
	R=1*		3.43*			15.09***			R=1**	7.85**				16.81***	15.59***
			4.04**			11.10***				6.67***				2.01	0.58
MYR PHP	P=7				2.07		4.31**	IDR VND PHP	P=7		15.75***			4.40**	1.88
	R=1*				4.31**		2.07		R=1***		7.44**			21.56***	22.17***
					2.14		0.84				0.03			17.60***	3.99**
SGD IDR THB	P=8	34.45***	0.13	22.94***				SGD IDR THB MYR	P=5	9.54***	3.15*	17.17***	9.73***		
	R=1***	22.98***	37.02***	35.81***					R=1***	23.11***	27.29***	30.08***	29.49***		
		32.31***	3.75**	5.08**						12.57***	10.37***	4.26**	0.04		

Appendix 1(2). Chi-Square Tests (cont'd)

Combination		SGD	IDR	THB	MYR	VND	PHP	Combination		SGD	IDR	THB	MYR	VND	PHP
SGD IDR VND PHP	P=5 R=1*	7.03***	0.59			1.18	5.08**	IDR MYR VND PHP	P=5 R=1***		2.89*		0.06	5.80**	1.76
		14.51***	13.42***			17.74***	17.34***				18.33***		19.67***	7.52*	12.37***
		5.72**	1.34			0.29	3.20*				0.70		0.02	6.65***	2.59
SGD THB MYR VND	P=5 R=2*	13.00***		12.14***	11.17***	13.35***		SGD IDR THB MYR VND	P=4 R=1*	7.27***	0.00	4.60**	0.47	9.56***	
		12.99***		12.72***	18.10***	11.38***				25.00***	27.25***	32.11***	36.54***	14.14***	
		8.10**		10.98***	8.05**	3.32				1.34	3.98**	1.45	8.20***	2.44	
IDR THB MYR VND	P=5 R=1*		0.80	1.67	0.19	5.26**		SGD IDR THB VND PHP	P=5 R=2*	6.28**	1.90	7.53**		11.61***	10.89***
			16.33***	12.44***	17.46***	3.08				13.70***	12.48***	15.05***		17.73***	17.11***
			2.06	0.00	0.50	4.78**				5.65*	1.24	0.59		9.93***	4.26

Note: P denotes lag order, and R denotes number of cointegration relationships. SGD denotes the Singapore dollar, IDR denotes the Indonesian rupiah, THB denotes the Thai baht, MYR denotes the Malaysian ringgit, VND denotes the Vietnamese dong, and PHP denotes the Philippine peso.

In each combination, the first row gives the test statistics for "data series are not included in the long-term equilibrium relationships," the second row gives the test statistics for "data series that are included in the cointegration system satisfy the property of stationarity, but the property of stationarity does not relate to other cointegration vectors," and the third row gives the test statistics for "data series that are included in the cointegration system have the property of weak exogeneity over the long run."

*** denotes significance at the 1% level.

** denotes significance at the 5% level.

* denotes significance at the 10% level.

Source: RIETI Discussion Paper Series 12-E-078.

Author's calculation.