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Inertia of the U.S. Dollar as a Key Currency through the Two Crises*

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Abstract

The current international monetary system with the U.S. dollar as a key currency is considered as the background of the U.S. dollar liquidity shortage during the global financial crisis. However, once facing a U.S. dollar liquidity shortage or crisis, financial institutions are likely to avoid their overdependence on the U.S. dollar. This implies that the international monetary system with the U.S. dollar as a key currency may be changed, especially during the global financial crisis even though key currencies show inertia due to network externalities in using international currencies. In this paper, we focus on the effects of both the global financial crisis and the euro zone crisis on the position of the U.S. dollar as a key currency in the current international monetary system. We base this on a theoretical framework in Ogawa and Sasaki (1998) in which a money-in-the-utility model is used to take into account the U.S. dollar's functions as both a medium of exchange and a store of value in the international currency competition. A parameter on the real balance of the U.S. dollar or its contribution to utility in the model is focused on, analyzing empirically whether both the global financial crisis and the euro zone crisis have changed its contribution to utility. One of the main empirical results from our models is that the contribution of the U.S. dollar to utility decreased during the global financial crisis. This corresponds to a period when financial institutions faced liquidity shortages from mid 2007 to late 2008. U.S. dollar liquidity shortage may have decreased the contribution of the U.S. dollar to utility.

Keywords: Key currency, Inertia, Liquidity shortage, Global financial crisis, Euro zone crisis, Monetary union, Money-in-the-utility model

JEL Classification Codes: F33, F41, G01

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1. Introduction

The global financial crisis brought about severer US dollar liquidity shortage in Europe as well as in the United States. It damaged balance sheets of both US and European financial institutions who invested in subprime mortgage backed securities. The damaged balance sheets of European financial institutions increased counterparty risks in interbank markets in Europe. They faced not only credit risk but also US dollar liquidity risk in the interbank markets.

Figure 1 shows movements in three spreads of London Interbank Offered Rate (LIBOR) (US dollar, 3 months) minus US Treasury Bills (TB) rate (US dollar, 3 months), LIBOR (US dollar, 3 months) minus Overnight Indexed Swap (OIS) rate (US dollar, 3 months), and OIS rate (US dollar, 3 months) minus US TB rate (US dollar, 3 months). The spread of LIBOR minus OIS rate is regarded as credit risk premium because LIBOR is the interest rate at which banks borrow unsecured funds from other banks while OIS rate is the interest rate at which banks borrow secured funds from other banks. Given that banks mainly face credit risk and liquidity risk, the spread of OIS rate in terms of US dollar minus US TB rate is regarded as US dollar liquidity risk premium.

We can find that the credit risk premium had increased since August 2007 and explains most of movements in a spread between LIBOR and US TB rate in and after the Lehman Brothers bankruptcy in September 2008. On one hand, the US dollar liquidity risk premium had already increased since 2005. It approached its peak from August 2007 to September 2008. However, it has decreased to a level smaller than 0.1% since the Federal Reserve Board (FRB) started quantitative easing monetary policy late 2008 when it at the same time concluded and extended currency swap arrangements[1] with other major central banks to provide US dollar liquidity to other countries.

The current international monetary system with the US dollar as a key currency is regarded as a background of the US dollar liquidity shortage in the global financial markets which include interbank markets in London. On the other hand, once financial institutions faced the US dollar liquidity shortage or crisis, they might try to avoid overdependence on the US dollar. It might change the international monetary system with the US dollar as a key currency especially in global financial market even though a key currency has inertia because of network externalities in using an international currency.

[1] The FRB concluded new currency swap arrangements with the European Central Bank (ECB) and the Swiss National Bank on December 12, 2007. Afterwards, it increased amount of currency swap arrangements and concluded them with other central banks.

In this paper, we focus on effects of both the global financial crisis and the euro zone crisis on a position of the US dollar as a key currency. Ogawa and Sasaki (1998) used a money-in-the-utility model to take into account both functions as medium of exchange and as store of value of the US dollar in the international currency competition. A parameter on real balances of the US dollar or a contribution of the US dollar to utility in the model was focused on to analyze empirically how strongly inertia of the US dollar as a key currency worked. We base on the theoretical framework to conduct an empirical analysis regarding an issue whether both the global financial crisis and the euro zone crisis have changed a contribution of the US dollar to utility. Ogawa and Kawasaki (2001) applied the methodology to estimate a coefficient on the US dollar in a utility function before and after the introduction of the euro. In addition, ECB (2015) reported recent situation regarding a role of the euro as an international currency.

In the next section, we explain our theoretical model according to Ogawa and Sasaki (1998) in order to take into account both functions as medium of exchange and as store of value of international currencies. In the third section, we base on the theoretical model to conduct empirical analysis on whether parameters on real balances of the US dollar and the euro or contributions of both of them to utility have changed after the global financial crisis and the euro zone crisis. From the analytical results, we can consider whether inertia of the US dollar as a key currency has been working through the two crises.

2. A theoretical model

(1) Setups of the model

We suppose that economic agents enjoy benefits from a function as medium of exchange by holding real balances of international currencies while they face costs of depreciating holding international currencies. We assume a money-in-the-utility model that a private sector has a utility function that real balances of international currencies as well as consumption depend on utility.

According to Ogawa and Sasaki (1998), we base on a Sidrauski (1967)-type of money-in-the-utility model[2] in which real balances of money as well as consumption are supposed as explanatory variables in a utility function. We extend the money-in-the-utility model to one with parallel international currencies. We suppose that private economic agents obtain utility by holding real balances of international currencies.

We focus on how the international currencies are held by private economic agents in

[2] Calvo (1981, 1985), Obstfeld (1981), Blanchard and Fischer (1989).

a third country. For simplicity, we suppose that two monetary authorities supply international currencies. The private sector in a third country holds international currencies as a result of its optimizing behavior. In other words, it has an optimal composition of international currencies to maximize utility. We define a key currency as an international currency that circulates dominantly in the world.

For convenience, we suppose that it is both the monetary authorities in country D and other countries O that supply their international currencies. The monetary authorities in country D supply currency D while the monetary authorities in other countries (represented by O) supply their own currencies (represented by O). The private sector in the third country, country A, is able to use both the currencies D and O as international currencies in international economic transactions.

The monetary authorities in country A adopt a flexible exchange rate system under which exchange rates of the home currency A in terms of both currencies D and O are flexible. We assume that a homogeneous basket of goods exist in the world economy and that the private sector can purchase the basket in exchange for currencies D or O.

The private sector can save both liquidity costs[3] and illiquidity costs[4] by holding international currency D or O for settlements of international economic transactions. The cost saving implies that international currencies give a liquidity service to the private sector. Thus we suppose that the private sector obtains utility by holding real balances of international currencies. We assume that both the international currencies are imperfect substitutes for the private sector in country A.

We suppose a situation that bonds in currencies D and O are available to the private sector in country A and that no bonds denominated in currency A are issued in country A. We make assumptions of perfect capital mobility and perfect substitution for bonds of different currencies. Moreover, we assume that the private sector has perfect foresight. Thus uncovered interest parity holds in the model. Also, we make assumptions of perfect flexible prices and a law of one price. Thus the purchasing power parity always holds in the model. For simplicity, we assume that its rate of time preference is constant over time and is equal to a real interest rate. Thus the real interest rate is constant over time.

(2) The private sector

The private sector in country A holds home currency A, international currencies D

[3] The liquidity cost is an enactment cost in the Baumol (1952) - Tobin (1956) type of transaction demand for money model.

[4] The illiquidity cost is a penalty cost of cash shortage in a precautionary demand for money model according to Whalen (1966).

and *O*, and bonds in currencies *D* and *O*.

Then, instantaneous budget constraints for the private sector are represented in real terms:

$$\dot{w}_t^p = \overline{r} w_t^p + y_t - c_t - \tau_t - i_t^A m_t^A - i_t^D m_t^D - i_t^O m_t^O \tag{1a}$$

$$w_t^p \equiv b_t^D + b_t^O + m_t^A + m_t^D + m_t^O \tag{1b}$$

where *y*: real gross domestic products, τ : real taxes, *c*: real consumption, i^A : nominal interest rate in currency *A*, i^D : nominal interest rate in currency *D*, i^O : nominal interest rate in currency *O*, w^p : real balance of financial assets held by the private sector, m^A : real balance of home currency A held by the private sector, m^D : real balance of currency D held by the private sector, m^O : real balance of currency *O* held by the private sector, b^D : real balance of bond in currency *D* held by the private sector, b^O : real balance of bond in currency in *O* held by the private sector, $\overline{r}$: real interest rate. Real interest rates in all countries are equal to each other by both the uncovered interest parity and purchasing power parity. A dot over variables implies a change in the relevant variables.

We assume no-Ponzi game conditions for the real balance of financial assets held by the private sector (w^p).

$$\lim_{t \to \infty} w_t^p e^{-\overline{r}t} \geq 0 \tag{2}$$

Equation (1a) can be rewritten as follows:

$$\dot{w}_t^p = \overline{r}\left(b_t^D + b_t^O\right) + y_t - c_t - \tau_t - \left(i_t^A - \overline{r}\right) m_t^A - \left(i_t^D - \overline{r}\right) m_t^D - \left(i_t^O - \overline{r}\right) m_t^O \tag{1a'}$$

It is noteworthy that the real balance of currencies, that is, zero-interest liabilities, are included as negative terms in the budget constraint equation (1a'). The terms represent costs of holding currencies for the private sector. It reflects that the private sector has to pay seignorage to the relevant monetary authorities once it holds the currencies. The seignorage mean inflation or depreciation of the relevant currencies and in turn lose the function as a store of value of the currencies.

We assume that the private sector maximizes its utility over an infinite horizon subject to budget constraints (1). We specify a Cobb-Douglas type of instantaneous utility function:

$$\int_0^\infty U\left(c_t, m_t^A, m_t^D, m_t^O\right) e^{-\delta t} dt \tag{3a}$$

$$U\left(c_t, m_t^A, m_t^D, m_t^O\right) \equiv \frac{\left[c_t^{\alpha}\left\{m_t^{A\beta}\left(m_t^{D\gamma} m_t^{O1-\gamma}\right)^{1-\beta}\right\}^{1-\alpha}\right]^{1-R}}{1-R} \tag{3b}$$

$$0<\alpha<1, 0<\beta<1, 0<\gamma<1, 0<R<1,$$

where δ : rate of time preference, R: reciprocal of instantaneous elasticity of substitution between intertemporal consumption σ :

$$\sigma \equiv -\frac{U_c}{U_{cc} c_t}$$

Given the Cobb-Douglas type of instantaneous utility function, an elasticity of substitution between international currencies is derived as follows:

$$\frac{U_{m^O}}{U_{m^D}} = \frac{1-\gamma}{\gamma} \frac{m_t^D}{m_t^O} \tag{4}$$

(3) The public sector

We assume that the public sector in country A holds only bonds in currencies D and O. Then, instantaneous budget constraints for the public sector are represented in real terms:

$$\dot{f}_t = \overline{r} f_t + \tau_t + \mu_t^A m_t^A - g_t \tag{5a}$$

$$f_t \equiv f_t^D + f_t^O \tag{5b}$$

where g: real government expenditures, f : foreign assets held by the public sector, μ^A : growth rate of currency A. We assume no-Ponzi game conditions for foreign assets held by the public sector.

$$\lim_{t\to\infty} f_t e^{-\overline{r}t} \geq 0 \tag{6}$$

A stock of foreign reserves held by the monetary authorities should be unchanged under a flexible exchange rate system because the authorities will not intervene in foreign exchange markets ($f_t = \overline{f}$). Also, the monetary authorities are able to control nominal money supply. Here we assume that the monetary authorities increase the nominal money supply at a constant growth rate $\overline{\mu}^A$.

Thus we obtain an instantaneous budget constraint equation for the public sector under a flexible exchange rate system:

$$g_t - \tau_t = \overline{r}\overline{f} + \overline{\mu}^A m_t^A \tag{7}$$

(4) Optimal composition of international currencies

From the instantaneous budget constraint equations for the private sector and the public sector equations (1a) and (7), we derive an instantaneous budget constraint equation for the whole economy of country *A* under a flexible exchange rate system:

$$\dot{b}_t^D + \dot{b}_t^O + \dot{m}_t^D + \dot{m}_t^O = \overline{r}\left(b_t^D + b_t^O + m_t^D + m_t^O + \overline{f}\right) + y_t - c_t - g_t - i_t^D m_t^D - i_t^O m_t^O \tag{8}$$

The private sector maximizes its utility functions (3a) and (3b) subject to budget constraint equation (8). We assume that the private sector has perfect foresight that economic variables do not diverge to infinity but converge to equilibrium values along a saddle path. The assumption rules out the possibility of multiplicity of equilibria in the model.

From the first-order conditions for maximization, we derive optimal real balances of international currencies:

$$m_t^D = \overline{m}^D = \frac{(1-\alpha)(1-\beta)\gamma}{\alpha}\frac{\overline{c}}{i_t^D} = \frac{(1-\alpha)(1-\beta)\gamma}{\alpha}\frac{\overline{c}}{\pi_t^D + \overline{r}} \tag{9a}$$

$$m_t^O = \overline{m}^O = \frac{(1-\alpha)(1-\beta)(1-\gamma)}{\alpha}\frac{\overline{c}}{i_t^O} = \frac{(1-\alpha)(1-\beta)(1-\gamma)}{\alpha}\frac{\overline{c}}{\pi_t^O + \overline{r}} \tag{9b}$$

where π_t^D : inflation rate of currency *D*, π_t^O : inflation rate of currency *O*,

$$\overline{c} = \overline{r}\left\{a_0 + \int_0^\infty y_t e^{-\overline{r}t}dt - \int_0^\infty g_t e^{-\overline{r}t}dt - \int_0^\infty (i_t^D m_t^D + i_t^O m_t^O)e^{-\overline{r}t}dt\right\}$$

From equations (9a) and (9b), an optimal composition ratio of international currencies ω is derived:

$$\omega_t \equiv \frac{m_t^D}{m_t^O} = \frac{\gamma}{1-\gamma}\frac{i_t^O}{i_t^D} = \frac{\gamma}{1-\gamma}\frac{\pi_t^O + \overline{r}}{\pi_t^D + \overline{r}} \tag{10}$$

A share ϕ of currency D is derived from the optimal composition ratio ω.

$$\phi_t \equiv \frac{m_t^D}{m_t^D + m_t^O} = \frac{\omega_t}{1+\omega_t} = \frac{1}{1+\dfrac{1-\gamma}{\gamma}\dfrac{i_t^D}{i_t^O}} = \frac{1}{1+\dfrac{1-\gamma}{\gamma}\dfrac{\pi_t^D + \overline{r}}{\pi_t^O + \overline{r}}} \tag{11}$$

Currency D is regarded as the key currency in the case where the share ϕ of currency D is larger than 50 percent.

From equations (10) and (11), the optimal composition ratio of international currencies and the share of the key currency depend on both the inflation or depreciation rates of the international currencies and a parameter γ in the instantaneous utility function equation (3b). Parameter γ indicates the degree of contribution of currency D to the utility of the private sector.

Given parameter γ, decreases in the inflation rate, or depreciation rate, of an international currency lead to decreases in the cost of holding the international currency. Thus the optimal composition ratio and the share of currency D increase as the inflation rate, or depreciation rate, decreases.

On the one hand, parameter γ has an effect on the optimal composition ratio and the share of currency D. An increase in parameter γ implies that holding the balance of currency D contributes more and more to an increase in utility. Given the inflation or depreciation rates of both the international currencies, increases in parameter γ lead to increases in the share of currency D.

3. Empirical analysis

(1) Models for estimating contribution of the US dollar and the euro to utility

According to the above mentioned theoretical model, a model for estimating a share of the US dollar is as follows.

$$\phi_t^D \equiv \frac{m_t^D}{m_t^D + m_t^O} = \frac{1}{1 + \frac{1-\gamma_t^D}{\gamma_t^D} \frac{i_t^D}{i_t^O}} = \frac{1}{1 + \frac{1-\gamma_t^D}{\gamma_t^D} \frac{\pi_t^D + \bar{r}}{\pi_t^O + \bar{r}}} \tag{12a}$$

where ϕ_t^D : a share of the US dollar in period t, m_t^D : a real balance of the UD dollar of private sector holdings in period t, m_t^O is real balances of other international currencies (the euro and the Japanese yen) of private sector holdings in period t, γ_t^D : a parameter or contribution of the real balance of the US dollar to the utility when compared with other currencies in period t, i_t^D : US dollar denominated nominal interest rate in period t, i_t^O : other international currencies (the euro and the Japanese yen) denominated nominal interest rate in period t, π_t^D : expected inflation rate in the

United States in period *t*, π_t^O : expected inflation rate in countries (the euro zone and Japan) with other international currencies in period *t*, $\bar{r}$: real interest rate.

Instead of the US dollar, a model for a share of the euro is as follows.

$$\phi_t^E \equiv \frac{m_t^E}{m_t^E + m_t^{O^*}} = \frac{1}{1+\dfrac{1-\gamma_t^E}{\gamma_t^E}\dfrac{i_t^E}{i_t^{O^*}}} = \frac{1}{1+\dfrac{1-\gamma_t^E}{\gamma_t^E}\dfrac{\pi_t^E+\bar{r}}{\pi_t^{O^*}+\bar{r}}} \tag{12b}$$

where ϕ_t^E : a share of the euro in period *t*, m_t^E : a real balance of the euro of private sector holdings in period *t*, $m_t^{O^*}$ is real balances of other international currencies (the US dollar and the Japanese yen) of private sector holdings in period *t*, γ_t^E : a parameter or contribution of the real balance of the euro to the utility when compared with other currencies in period *t*, i_t^E : euro denominated nominal interest rate in period *t*, $i_t^{O^*}$: other international currencies (the US dollar and the Japanese yen) denominated nominal interest rate in period *t*, π_t^E : expected inflation rate in the euro zone in period *t*, $\pi_t^{O^*}$: expected inflation rate in countries (the United States and Japan) with other international currencies in period *t*.

We use equations (12a) and (12b) to estimate the parameters γ_t^D and γ_t^E which indicates the degree of contribution of the US dollar and the euro to utility, respectively. The contribution of the US dollar to utility γ_t^D is transformed from equations (12a) into the following equations:

$$\gamma_t^D = \frac{1}{1+\left(\dfrac{1}{\phi_t^D}-1\right)\dfrac{i_t^O}{i_t^D}} \tag{13a}$$

$$\gamma_t^D = \frac{1}{1+\left(\dfrac{1}{\phi_t^D}-1\right)\dfrac{\pi_t^O+\bar{r}}{\pi_t^D+\bar{r}}} \tag{13b}$$

Similarly, the contribution of the euro to utility γ_t^E is transformed from equations

(12b) into the following equations:

$$\gamma_t^E = \frac{1}{1+\left(\frac{1}{\phi_t^E}-1\right)\frac{i_t^{O^*}}{i_t^E}} \tag{14a}$$

$$\gamma_t^E = \frac{1}{1+\left(\frac{1}{\phi_t^E}-1\right)\frac{\pi_t^{O^*}+\bar{r}}{\pi_t^E+\bar{r}}} \tag{14b}$$

In this paper, we use the models (13a) and (14a) to conduct empirical analysis of estimating contributions of the US dollar and the euro to utility by using data on 3-month or 6-month nominal interest rate. In addition, we use the models (13b) and (14b) to conduct empirical analysis of estimating contributions of the US dollar and the euro to utility by setting 1.5%, 2.0%, 2.5%, or 3.0% as a real interest rate[5]. Since the nominal interest rate is fluctuating sharply, the models (13a) and (14a) is fluctuating sharply. By contrast, the models (13b) and (14b) is stable because the expected inflation rate is relatively stable and the real interest rate is fixed. We thought that only the models (13a) and (14a) of fluctuating sharply cannot be obtained robustness result. Therefore, we also analyzed the stable models (13b) and (14b).

(2) Analytical periods

A whole sample period covers a period from 1986Q1 to 2014Q4. In the first analysis, we investigate whether the introduction of the euro on January 1, 1999 had any effect on contributions of the US dollar to utility. We divide the whole sample period into two sub-sample periods which include a period from 1986Q1 to 1998Q4 and a period from 1999Q1 to 2014Q4. We call these sub-sample periods as sub-sample periods 1(a) and 1(b). We analyze differences in contributions the US dollar between sub-sample periods 1(a) and 1(b) to investigate effects of the introduction of euro on contribution of the US dollar to utility.

In the second analysis, we investigate whether the collapse of the housing bubble in the United States in 2006Q2 had any effects on contributions of the US dollar to utility. We divide the whole sample period into three sub-sample periods which include a period from 1986Q1 to 1998Q4, a period from 1999Q1 to 2006Q1, and a period from 2006Q2 to 2014Q4. We call these sub-sample periods as sub-sample periods 2(a), 2(b), and 2(c).

[5] Ogawa and Kawasaki (2001) assumed that real interest rates were 3.0%, 5.0%, and 8.0% in the previous study on inertia of the US dollar as a key currency before and after the introduction of the euro.

The collapse of American real estate bubble occurred in 2006Q2. We analyze differences in contributions the US dollar and the euro between sub-sample periods 2(b) and 2(c) to investigate effects of the collapse of the housing bubble on contribution of the US dollar and the euro to utility.

In the third analysis, we investigate whether the global financial crisis, especially the BNP Paribas shock in 2007Q3 had any effects on contributions of the US dollar to utility. We divide the whole sample period into three sub-sample periods which include a period from 1986Q1 to 1998Q4, a period from 1999Q1 to 2007Q2, and a period from 2007Q3 to 2014Q4. We call these sub-sample periods as sub-sample periods 3(a), 3(b), and 3(c). We analyze differences in contributions the US dollar and the euro between sub-sample periods 3(b) and 3(c) to investigate effects of the BNP Paribas shock on contribution of the US dollar and the euro to utility. Financial institutions faced the US dollar liquidity shortage during the sub-sample period 3(c).

In the fourth analysis, we investigate whether the global financial crisis, especially the bankruptcy of Lehman Brothers in September 2008 had any effects on contributions of the US dollar and the euro to utility. We divide the whole sample period into three sub-sample periods which include a period from 1986Q1 to 1998Q4, a period from 1999Q1 to 2008Q2, and a period from 2008Q3 to 2014Q4. We call these sub-sample periods as sub-sample periods 4(a), 4(b), and 4(c). We analyze differences in contributions the US dollar and the euro between sub-sample periods 4(b) and 4(c) to investigate effects of the Lehman shock on contribution of the US dollar and the euro to utility. Financial institutions faced the US dollar liquidity risk as well as credit risk during the sub-sample period 4(c).

In the fifth analysis, we investigate whether the euro zone crisis had any effects on contributions of the US dollar and the euro to utility. The euro zone crisis started once the Greek debt crisis occurred late in 2009. We divide the whole sample period into three sub-sample periods which include a period from 1986Q1 to 1998Q4, a period from 1999Q1 to 2009Q3, and a period from 2009Q4 to 2014Q4. We call these sub-sample periods as sub-sample periods 5(a), 5(b), and 5(c). We analyze differences in contributions the US dollar and the euro between sub-sample periods 5(b) and 5(c) to investigate effects of the euro zone crisis on contribution of the US dollar and the euro to utility.

(3) Data

The shares of the US dollar and the euro are calculated according to the theoretical model in which we regard that the real balances of international currencies contribute to utility. However, it is difficult to obtain data on the real balance of international currency which include the US dollar, the euro and the Japanese yen held by private sector in the world economy. Instead, we use BIS data on total of domestic currency denominated debt and foreign currency denominated debt of the euro currency market according to the previous study (Ogawa and Sasaki (1998) and Ogawa and Kawasaki (2001)). Specifically, we use total data of domestic currency (the US dollar) denominated debt and foreign currency (the US dollar) denominated debt of the euro currency market as m_t^D. The data are obtained from a BIS (Bank for International Settlements) website. Given a data constraint that the data are quarterly, we have to use quarterly data of other variables to conduct the empirical analysis.

100% stacked area charts of domestic currency denominated debt and foreign currency denominated debt of the euro currency market are shown in Figures 2a to 2c. Figure 2a shows movements in shares of domestic currency denominated debt of the euro currency market classified by currencies. The share of the US dollar has increased while the share of the euro has decreased in 1998Q4. Figure 2b shows movements in shares of foreign currency denominated debt of the euro currency market classified by currencies. The share of the US dollar has decreased while the share of the euro has increased in 1998Q4. The decreases in the share of the euro occurred because euro zone currencies have replaced the euro by the introduction of the euro. In other words, euro zone residents increased domestic currency (the euro) and decrease foreign currency (the euro zone currencies except home currencies). Figure 2c shows movements in shares of total of domestic currency denominated debt and foreign currency denominated debt of the euro currency market classified by currencies. In this figure, the share of the euro has increased little by little because the above effects were canceled out and.

We use 3-month LIBOR and 6-month LIBOR data as the nominal interest rate. The data are obtained from IMF, International Financial Statistics (IFS) CD-ROM. Each of i_t^O and $i_t^{O^*}$ is a weighted average of nominal interest rates in terms of two other currencies for the US dollar and the euro, respectively. The weights are based on outstanding of foreign currency denominated debts. Data on the euro denominated nominal interest rate are not available from 1986Q1 to 1998Q4. Instead, we use an arithmetical average the LIBOR in terms of the French franc, the Deutsche Mark and the Netherland Guilder. The data are obtained from *International Financial Statistics CD-ROM* (IMF).

Expected inflation rates are calculated from price level and expected price level. We assume that the price level of each period is follow ARIMA (p, d, q) process. Secondly, we use monthly data on the price level for the last five years to estimate an ARIMA model. The Augmented Dickey - Fuller test is used to unit root test. The AIC is used for lag selection. Thirdly, the estimated ARIMA model is used to predict a price level of one period ahead. Finally, we use the actual price level and the predicted price level of one period ahead to calculate the expected inflation rate. Consumer price index data are used as the price level. The data are obtained from FRED website.

The expected inflation rate in the euro zone is a weighted average of the expected inflation rate in the original euro zone countries. They include Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, Netherlands, Portugal, and Spain. A weight in calculating a weighted average of the expected inflation rate is based on GDP share among the countries. The data obtained from Penn World Table website[6].

(4) Analytical method

We conduct point estimation for parameters or contributions of the US dollar and the euro to utility at each period. Based on the point estimation, we calculate a mean value of the contribution at each of the sub-sample periods. We compare the mean values among the sub-sample periods to investigate whether the contribution of the currency to utility statistically significantly increased or decreased. For the purpose, we use the Welch's t test to test difference in the mean values among the sub-sample periods.

The Welch's t test is used to test whether the population mean of the two samples is the same. Hypothesis is as follows:

H_0: The population mean of the two samples is equal.

H_1: The population mean of the two samples is not equal.

If the null hypothesis is not rejected, the contribution of the currency to utility is not statistically significantly regarded to change over time between the relevant sub-sample periods. If the null hypothesis is rejected and the mean value increases (decreases), the contribution of the currency to utility is considered to increase (decrease) over time between the relevant sub-sample periods. The above method is used to analyze the changes of the contribution of the currency to utility before and after the events which include the global financial crisis and the euro zone crisis as well as the introduction of the euro.

(5) Analytical results

[6] See Feenstra, Inklaar and Timmer (2013) for reference.

Time series of contribution of the US dollar to utility are shown in Figures 3a to 3f. On one hand, Time series of contribution of the euro to utility are shown in Figures 4a to 4f.

We conduct the above-mentioned point estimation for the contributions of the US dollar and the euro to utility from1986Q1 to 2014Q4. We exclude results of point estimation in 1997Q4, 2003Q4, 2006Q4, 2008Q4, 2011Q4, and 2014Q1 in the case of setting 1.5% as a real interest rate in the model (13b) and model (14b) because it is clear that they are outliers which exceed plus/minus one standard deviation from its estimation. We also exclude results of point estimation in same periods at the cases of setting 2.0%, 2.5%, and 3.0% as a real interest rate in the model (13b) and model (14b).

Table 1 shows empirical results of the contribution of the US dollar to utility at the sub-sample periods 1(a) and 1(b). The whole sample period is divided into the sub-sample periods 1(a) and 1(b) to analyze effects of the introduction of the euro on the contribution of the US dollar to utility. In Table 1, the first row shows which model is used for estimation of the contributions of the US dollar to utility. The first line shows results of in the case of using data on 3-month nominal interest rate in the model (13a). The second line shows results in the case of using data on 6-month nominal interest rate in the model (13a). The third line shows results in the case of setting 1.5% as a real interest rate in the model (13b). The fourth line shows results in the case of setting 2.0% as a real interest rate in the model (13b). The fifth line shows results in the case of setting 2.5% as a real interest rate in the model (13b). The sixth line shows results in the case of setting 3.0% as a real interest rate in the model (13b).

Rows of "Contribution of dollar (Average)" show means of the contribution of the US dollar to utility in each of whole sample period and sub-sample periods. Row (a) shows means of the contribution of the US dollar to utility before the introduction of euro. Row (b) shows means of the contribution of the US dollar to utility after the introduction of euro. Means of the contribution of the US dollar to utility before the introduction of euro are 0.56-0.57. On the other hand, means of the contribution of the US dollar to utility after the introduction of euro are 0.50-0.52.

Row of "Welch's t test of (a) and (b)" shows p-values of the Welch's t test and rejection or not of the hypothesis of equal means between sub-sample periods (a) and (b) at a significance level 99%. The results of the Welch's t test of (a) and (b) show that the hypothesis of equal means between sub-sample periods (a) and (b) are not rejected in the models (13a) and the cases of setting 1.5% as a real interest rate in the model (13b). It implies that the contribution of the US dollar to utility has not changed before and after the introduction of the euro. The contribution has been stable at 0.53-0.54 in the whole sample period. In contrast, the results of the Welch's t test of (a) and (b) show that the hypothesis of equal means between sub-sample periods (a) and (b) are rejected at the cases of setting 2.0%, 2.5%, and 3.0% as a real interest rate in the model (13b). It implies that the contribution of the US dollar to utility has changed before and after the introduction of the euro. We obtained mixed analytical results regarding effects of the introduction of the euro on the contribution of the US dollar to utility.

Table 2 shows analytical results of the contribution of the euro to utility at the sub-sample periods 1(a) and 1(b). The contribution of the euro to utility is 0.24 before the introduction of the euro. That is 0.32-0.37 after the introduction of the euro. The results of the Welch's t test (a) and (b) show that the hypothesis of equal means between sub-sample periods (a) and (b) are rejected at all of the models. It implies that the contribution of the euro to utility has made statistically significant change before and after the introduction of the euro.

Table 3 shows analytical results of the contribution of the US dollar to utility at the sub-sample periods 2(a), 2(b), and 2(c). The three sub-sample periods are divided to focus on effects of the collapse of American real estate bubble as well as the introduction of the euro. The contribution of the US dollar to utility is 0.56-0.57 at the sub-sample period (a) or before the introduction of the euro. The contribution of the US dollar to utility is 0.53-0.57 at the sub-sample period (b) or before the collapse of American real estate bubble (after the introduction of the euro). Results of the Welch's t test of (a) and (b) show that the hypothesis of equal means between sub-sample periods (a) and (b) is not rejected at all of the models. It implies that the contribution of the US dollar has not changed over time before the collapse of American real estate bubble.

Column (c) shows that the contribution of the US dollar to utility is 0.45-0.51 after the collapse of American real estate bubble. The results of the Welch's t test of (b) and (c) show that the hypothesis of equal means between sub-sample periods (b) and (c) is rejected in models (13a). It implies that the contribution of the US dollar to utility has changed before and after the collapse of American real estate bubble. On one hand, the results of the Welch's t test of (b) and (c) show that the hypothesis of equal means between sub-sample periods (b) and (c) is not rejected in the models (13b). Throughout the whole of sample period, the contribution of the US dollar to utility has been stable at 0.53-0.54 for all of models (13b). We obtained mixed analytical results regarding effects of the collapse of American real estate bubble on the contribution of the US dollar to utility.

Table 4 shows analytical results of the contribution of the euro to utility at the sub-sample periods 2(a), 2(b), and 2(c). The contribution of the euro is 0.24 before the introduction of euro. The contribution of the euro to utility before the collapse of American real estate bubble (in after the introduction of the euro) is 0.30-0.33. The results of Welch's t test of (a) and (b) show that the hypothesis of equal means between sub-sample periods (a) and (b) is rejected at all of the models. It implies that the contribution of the euro to utility has increased before the collapse of American real estate bubble. The contribution of the euro to utility is 0.33-0.41 after the collapse of American real estate bubble. The results of the Welch's t test of (b) and (c) show that the hypothesis of equal means between sub-sample periods (b) and (c) is not rejected in the models (14a) and the cases of setting 1.5% and 2.0% as a real interest rate in the model (14b). It implies that the contribution of the euro to utility has not changed before and after the collapse of American real estate bubble. On one hand, the results of the Welch's t test of (b) and (c) show that the hypothesis of equal means between sub-sample periods (b) and (c) is rejected in the cases of setting 2.5% and 3.0% as a real interest rate in the model (14b). It implies that the contribution of the euro to utility has changed before and after the collapse of American real estate bubble. We obtained mixed analytical results regarding effects of the collapse of American real estate bubble on the contribution of the euro to utility.

Table 5 shows analytical results of the contribution of the US dollar to utility at the sub-sample periods 3(a), 3(b), and 3(c) by focusing on effects of the BNP Paribas shock on the contribution of the US dollar to utility. The contribution of the US dollar to utility is 0.56-0.57 before the introduction of euro. Column (b) shows the contribution of the US dollar to utility is 0.53-0.58 before the BNP Paribas shock and after the introduction of the euro. The results of the Welch's t test of (a) and (b) show that the hypothesis of equal means between sub-sample periods (a) and (b) is not rejected at all of the models. It implies that the contribution of the US dollar to utility has not changed over time before the BNP Paribas shock.

Column (c) shows that the contribution of the US dollar to utility is 0.42-0.50 after the BNP Paribas shock. The results of the Welch's t test of (b) and (c) show that the hypothesis of equal means between sub-sample periods (b) and (c) is rejected in the model (13a) and the cases of setting 2.5% and 3.0 as a real interest rate in the model (13b). The contribution of the US dollar to utility has made statistically significant change before and after the BNP Paribas shock. The contribution of the US dollar to utility has decreased to 0.42-0.49. On one hand, the results the Welch's test of (b) and (c) show that the hypothesis of equal means between sub-sample periods (b) and (c) is not rejected in the cases of setting the 1.5% and 2.0 as a real interest rate in the model (13b). Throughout the all of the sample period, the contribution of the US dollar to utility has been stable at 0.54 in the cases of setting the 2.5% and 3.0 as a real interest rate in the model (13b). We obtained mixed analytical results regarding effects of the BNP Paribas shock on the contribution of the US dollar to utility.

Table 6 shows analytical results of the contribution of the euro to utility at the sub-sample periods 3(a), 3(b), and 3(c) by focusing on effects of the BNP Paribas shock on the contribution of the US dollar to utility. The contribution of the euro to utility is about 0.24 before the introduction of the euro. The contribution of the euro to utility is 0.30-0.32 before the BNP Paribas shock and the after introduction of euro. The results of the Welch's t test of (a) and (b) show that the hypothesis of equal means between sub-sample periods (a) and (b) is rejected at all of the models. The contribution of the euro to utility had increased before and after the introduction of the euro before BNP Paribas shock.

The contribution of the euro to utility is 0.34-0.43 after the BNP Paribas shock. The results of the Welch's t test of (b) and (c) show that the hypothesis of equal means between sub-sample periods (b) and (c) is rejected at all of the models except for the case of setting 1.5% as a real interest rate in the model (14b). The contribution of the euro to utility has not changed before and after the BNP Paribas shock though the hypothesis is rejected in the case of setting 1.5% as a real interest rate in the model (14b).

Table 7 shows results of analysis of the contribution of the US dollar to utility at the sub-sample periods 4(a), 4(b), and 4(c) by focusing on effects of the Lehman Brothers bankruptcy on the contribution of the US dollar to utility. The contribution of the US dollar to utility is 0.56-0.57 before the introduction of the euro. The contribution of the US dollar to utility is 0.52-0.57 before the Bankruptcy of Lehman Brothers and after the introduction of euro. The results of the Welch's t test of (a) and (b) show that the hypothesis of equal means between sub-sample periods (a) and (b) is not rejected at all of the models except for the case of setting 3.0% as a real interest rate in the model (13b). It implies that the contribution of the US dollar significantly had not changed before the bankruptcy of Lehman Brothers even though the euro was introduced though the hypothesis is rejected in the case of setting 3.0% as a real interest rate in the model (13b).

The contribution of the US dollar to utility is 0.42-0.50 after the Lehman Brothers bankruptcy. The results of the Welch's t test of (b) and (c) show that the hypothesis of equal means between sub-sample periods (b) and (c) is rejected in models (13a). It implies that the contribution of the US dollar to utility has decreased before and after the Lehman Brothers bankruptcy. On one hand, the results of the Welch's t test of (b) and (c) show that the hypothesis of equal means between sub-sample periods (b) and (c) is not rejected in models (13b). It implies that the contribution of the US dollar to utility has been stable at about 0.54 throughout the whole of the sample period in the case of using model (13b) except for the case of setting 3.0% as a real interest rate. We obtained mixed analytical results regarding effects of the Lehman Brothers bankruptcy on the contribution of the US dollar to utility.

Table 8 shows results of analysis of the contribution of the US dollar to utility at the sub-sample periods 4(a), 4(b), and 4(c) by focusing on effects of the Lehman Brothers bankruptcy on the contribution of the euro to utility. The contribution of the euro to utility is 0.24 before the introduction of the euro to utility. The contribution of the euro to utility is 0.30-0.33 before the Lehman Brothers bankruptcy and after the introduction of euro. The results of the Welch's t test of (a) and (b) show that the hypothesis of equal means between sub-sample periods (a) and (b) is rejected at all of the models. It implies that the introduction of the euro increased the contribution of the euro to utility before the Lehman Brothers bankruptcy.

The contribution of the euro to utility is 0.34-0.44 after the Lehman Brothers bankruptcy. The results of the Welch's t test of (b) and (c) show that the hypothesis of equal means between sub-sample periods (b) and (c) is not rejected in the cases of setting 1.5% and 2.0% as a real interest rate in the model (14b). It implies that the contribution of the euro to utility has not changed before and after the Lehman Brothers bankruptcy. On one hand, the results of the Welch's t test of (b) and (c) show that the hypothesis of equal means between sub-sample periods (b) and (c) is rejected in the models (14a) and the cases of setting 2.5% and 3.0% as a real interest rate in the model (14b). It implies that the contribution of the euro to utility has changed before and after the Lehman Brothers bankruptcy.

Table 9 shows results of analysis of the contribution of the US dollar to utility at the sub-sample periods 5(a), 5(b), and 5(c) by focusing on effects of the Greek debt crisis on the contribution of the US dollar to utility. The contribution of the US dollar to utility is 0.56-0.57 before the introduction of euro. The contribution of the US dollar to utility is 0.52-0.55 before the Greek debt crisis and after the introduction of euro. The results of the Welch's t test of (a) and (b) show that the hypothesis of equal means between sub-sample periods (a) and (b) is not rejected at all the models except for the case of setting 3.0% as a real interest rate in the model (13b). It implies that the introduction of the euro did not change the contribution of dollar before the Greek debt crisis though the hypothesis is rejected in the case of setting 3.0% as a real interest rate in the model (13b).

The contribution of the US dollar to utility is 0.43-0.50 after the Greek debt crisis.

The results of the Welch's t test of (b) and (c) show that the hypothesis of equal means between sub-sample periods (b) and (c) is not rejected at all of the models except for the case of using data on 6-month nominal interest rate in the model (13a). It implies that the contribution of the US dollar to utility has not changed before and after the Greek debt crisis though the hypothesis is rejected in the case of using data on 6-month nominal interest rate in the model (13a).

Table 10 shows results of analysis of the contribution of the euro to utility at the sub-sample periods 5(a), 5(b), and 5(c) by focusing on effects of the Greek debt crisis on the contribution of the euro to utility. The contribution of the euro to utility is 0.24 before the introduction of the euro. The contribution of the euro to utility is 0.31-0.35 before the Greek debt crisis and after the introduction of the euro. The results of the Welch's t test of (a) and (b) show that the hypothesis of equal means between sub-sample periods (a) and (b) is rejected at all of the models. The introduction of the euro increased the contribution of the euro to utility before the Greek debt crisis.

The contribution of the euro to utility is 0.34-0.43 after the Greek debt crisis. The results of Welch's t test of (b) and (c) show that the hypothesis of equal means between sub-sample periods (b) and (c) is not rejected at all the models except for the case of setting 3.0% as a real interest rate in the model (14b). It implies that the contribution of the euro to utility has not changed before and after the Greek debt crisis though the hypothesis is rejected in the case of setting 3.0% as a real interest rate in the model (14b).

In summary, Table 1 shows mixed results regarding decreases in contribution of the US dollar to utility. The reason might be that the latter sub-sample period includes the crises while Table 2 shows that the contribution of the euro to utility increased after the introduction of the euro. Tables 3, 5, 7, and 9 show that the contribution of the US dollar to utility has not changed before and after the introduction of the euro in almost of the cases. On one hand, Tables 4, 6, 8, and 10 show that the contribution of the euro to utility has made statistically significant change before and after it in all of the cases. Tables 3, 5, and 7 show mixed results regarding effects of the collapse of US housing bubble burst, the BNP Paribas shock, and the Lehman Brothers bankruptcy on the contribution of the US dollar to utility. In the largest number of cases (4 of 6 cases), contribution of the US dollar to utility significantly decreased after the BNP Paribas shock in 2007Q3. The timing corresponds to the global financial crisis from mid in 2007 to late in 2008 that financial institutions faced the US dollar liquidity shortage. Tables 2, 4, 6, and 8 show that the contribution of the euro to utility has not significantly change in almost of the cases through the global financial crisis. Tables 9 and 10 show that the contribution of both the US dollar and the euro to utility has not significantly changed in almost of the cases before and after the euro zone crisis. It implies that contribution of the US dollar to utility has return to a previous level after the euro zone crisis though it decreased during the global financial crisis.

Finally, we investigate which factor has played as a role of driving force. For this purpose, we obtain a total differential of each of the models (13a) to (14b) as follows:

$$\begin{aligned} d\gamma_t^D &= \frac{\partial \gamma_t^D}{\partial \phi_t^D} d\phi_t^D + \frac{\partial \gamma_t^D}{\partial i_t^O} di_t^O + \frac{\partial \gamma_t^D}{\partial i_t^D} di_t^D \\ &\approx \frac{\partial \gamma_t^D}{\partial \phi_t^D}(\phi_{t+1}^D - \phi_t^D) + \frac{\partial \gamma_t^D}{\partial i_t^O}(i_{t+1}^O - i_t^O) + \frac{\partial \gamma_t^D}{\partial i_t^D}(i_{t+1}^D - i_t^D) \end{aligned} \tag{13a'}$$

$$\begin{aligned} d\gamma_t^D &= \frac{\partial \gamma_t^D}{\partial \phi_t^D} d\phi_t^D + \frac{\partial \gamma_t^D}{\partial \pi_t^O} d\pi_t^O + \frac{\partial \gamma_t^D}{\partial \pi_t^D} d\pi_t^D \\ &\approx \frac{\partial \gamma_t^D}{\partial \phi_t^D}(\phi_{t+1}^D - \phi_t^D) + \frac{\partial \gamma_t^D}{\partial \pi_t^O}(\pi_{t+1}^O - \pi_t^O) + \frac{\partial \gamma_t^D}{\partial \pi_t^D}(\pi_{t+1}^D - \pi_t^D) \end{aligned} \tag{13b'}$$

$$\begin{aligned} d\gamma_t^E &= \frac{\partial \gamma_t^E}{\partial \phi_t^E} d\phi_t^E + \frac{\partial \gamma_t^E}{\partial i_t^{O^*}} di_t^{O^*} + \frac{\partial \gamma_t^E}{\partial i_t^E} di_t^E \\ &\approx \frac{\partial \gamma_t^E}{\partial \phi_t^E}(\phi_{t+1}^E - \phi_t^E) + \frac{\partial \gamma_t^E}{\partial i_t^{O^*}}(i_{t+1}^{O^*} - i_t^{O^*}) + \frac{\partial \gamma_t^E}{\partial i_t^E}(i_{t+1}^E - i_t^E) \end{aligned} \tag{14a'}$$

$$\begin{aligned} d\gamma_t^E &= \frac{\partial \gamma_t^E}{\partial \phi_t^E} d\phi_t^E + \frac{\partial \gamma_t^E}{\partial \pi_t^{O^*}} d\pi_t^{O^*} + \frac{\partial \gamma_t^E}{\partial \pi_t^E} d\pi_t^E \\ &\approx \frac{\partial \gamma_t^E}{\partial \phi_t^E}(\phi_{t+1}^E - \phi_t^E) + \frac{\partial \gamma_t^E}{\partial \pi_t^{O^*}}(\pi_{t+1}^{O^*} - \pi_t^{O^*}) + \frac{\partial \gamma_t^E}{\partial \pi_t^E}(\pi_{t+1}^E - \pi_t^E) \end{aligned} \tag{14b'}$$

The larger term of the right-hand side of the above equations means that a change in the relevant variable has the stronger influence to a change in the contribution to utility. We regard the variable as a stronger driving force for a change in the contribution to utility.

Table 11 shows an average of each term of the right-hand side in the model (13a'). The US dollar denominated nominal interest rate and other international currencies (the euro and the Japanese yen) denominated nominal interest rate have stronger influence on the contribution to utility. Both of the nominal interest rates are regarded as stronger driving forces of the model (13a).

Table 12 shows an average of each term of the right-hand side in the model (13b'). It is clear that the expected inflation rate in the United States has larger influence on the contribution to utility. The expected inflation rate in the United States is regarded as a stronger driving force of the model (13b).

Table 13 shows an average of each term of the right-hand side in the model (14a'). The euro denominated nominal interest rate and the other international currencies (the US dollar and the Japanese yen) denominated nominal interest rate have larger influence on the contribution to utility. Both of the nominal interest rates are regarded as stronger driving forces of the model (14a).

Table 14 shows an average of each term of the right-hand side in the model (14b'). It is clear that the expected inflation rate in countries (the United States and Japan) with other international currencies have stronger influence on the contribution to utility. the expected inflation rates in countries (the United States and Japan) with other international currencies are regarded as stronger driving forces of the model (13b). From the results, we conclude that nominal interest rates or expected inflation rates are stronger driving forces for changes in the contributions to utility.

4. Conclusion

In this paper, we estimated the contributions of the US dollar or the euro to utility that are based on the money-in-the-utility model with international currencies to investigate effects of the global financial crisis and the euro zone crisis as well as the introduction of the euro on inertia of the US dollar as a key currency. We obtained the following empirical results.

First, the introduction of the euro had no effects on the contributions of the US dollar to utility while it had some effects on the contribution of the euro to utility. We still have inertia of the US dollar as a key currency even though a single common currency created in Europe. On one hand, it is clear that the creation of a single common currency increased functions of the euro as an international currency.

Second, we found that the contribution of the US dollar to utility was likely to decrease when we experienced the global financial crisis which included the BNP Paribas shock (in 2007Q3) and the Lehman Brother bankruptcy (in 2008Q3) in some of models. The timing corresponds to a period when financial institutions faced liquidity shortage from mid in 2007 to late in 2008. The US dollar liquidity shortage might decrease the contribution of the US dollar to utility. On one hand, we cannot find any changes in the contribution of the euro to utility in almost of the cases during the global financial crisis.

Third, we find no changes in the contribution of both the US dollar and the euro to utility after the Greek debt crisis happened in almost of the cases. At the same time, the FRB conducted a quantitative easing monetary policy to provide huge amount of US dollar liquidity not only to the US economy but also to Europe though currency swap arrangements of the FRB with central banks in Europe.

We can conclude that liquidity supply of a key currency in itself rather than creation of a single common currency in a European region might affect changes in the contribution of the international currency to utility or, in other words, inertia of the US dollar as a key currency. Given the result, we have a policy implication. Liquidity supply is important for the US dollar to be stabilized at the position as a key currency. The FRB should manage the US dollar liquidity in the world economy through currency swap arrangements with other central banks in order to stabilize the current international monetary system with the US dollar as a key currency. In addition, a credit line for a liquidity crisis provided by the IMF should be effective for stability of the current international monetary system. As well, a regional monetary cooperation which includes CMIM Precautionary Facility as well as multilateral currency swap arrangements under the Chiang Mai Initiative should be effective in providing liquidity to a liquidity crisis-hit country.

References

Baumol W. J., 1952. The transactions demand for cash: An inventory theoretic approach. Quarterly Journal of Economics, 66, 545-556.

Blanchard, O. J. and S. Fischer, 1989. Lectures on Macroeconomics, MIT Press, Cambridge, MA.

Calvo, G. A., 1981. Devaluation: Level versus rates. Journal of International Economics, 11, 165-172.

Calvo, G. A., 1985. Currency substitution and the real exchange rate: The utility maximization approach, Journal of International Money and Finance, 4, 175-188.

European Central Bank, 2015, The International Role of the Euro, Frankfurt, Germany.

Feenstra, R. C., R. Inklaar and M. P. Timmer, 2013. The Next Generation of the Penn World Table available for download at www.ggdc.net/pwt

Matsuyama, K., N. Kiyotaki, and A. Matsui, 1993. Toward a Theory of International Currency, Review of Economic Studies, 60, 283-307.

Obstfeld M., 1981. Macroeconomic policy, exchange-rate dynamics, and optimal asset accumulation. Journal of Political Economy, 89, 1142-1161.

Ogawa, E. and K. Kawasaki, 2001 Effects of the introduction of the euro on international monetary system, Hitotsubashi University Graduate School of Commerce and Management Discussion Paper, No. 63 (in Japanese).

Ogawa E. and Y. N. Sasaki, 1998. Inertia in the key currency, Japan and the World Economy, 10, 421-439.

Tobin, J., 1956. The interest elasticity of transaction demand for cash. Review of Economics and Statistics, 38, 341-247.

Trejos, A. and R. Wright, 1996. Search-theoretic Models of International Currency, Review, Federal Reserve Bank of St. Louis, 78, 117-132.

Welch, B. L., 1938. The significance of the difference between two means when the population variances are unequal. *Biometrika*, 29, 350-362.

Wharlen, E.L., 1966. A rationalization of the precautionary demand for cash. Quarterly Journal of Economics, 80, 314-324.

Table 1: Contribution of the US dollar to utility at the sub-sample periods 1(a) and 1(b)

	Contribution of dollar(Average)			Welch's t test of (a) and (b)	
Model	whole	(a)	(b)	p-value	H_0(significance level 99%)
(13a) 3-month nominal interest rate	0.53	0.57	0.50	0.02	not rejected
(13a) 6-month nominal interest rate	0.54	0.57	0.51	0.02	not rejected
(13b) 1.5% real interest rate	0.54	0.56	0.52	0.01	not rejected
(13b) 2.0% real interest rate	0.54	0.56	0.52	0.00	rejected
(13b) 2.5% real interest rate	0.54	0.56	0.51	0.00	rejected
(13b) 3.0% real interest rate	0.53	0.56	0.51	0.00	rejected

*whole:1986Q1-2014Q4,(a):1986Q1-1998Q4,(b):1999Q1-2014Q4

Table2: Contribution of the euro to utility at the sub-sample periods 1(a) and 1(b)

	Contribution of euro(Average)			Welch's t test of (a) and (b)	
Model	whole	(a)	(b)	p-value	H_0(significance level 99%)
(14a) 3-month nominal interest rate	0.31	0.24	0.37	0.00	rejected
(14a) 6-month nominal interest rate	0.31	0.24	0.36	0.00	rejected
(14b) 1.5% real interest rate	0.28	0.24	0.32	0.00	rejected
(14b) 2.0% real interest rate	0.28	0.24	0.32	0.00	rejected
(14b) 2.5% real interest rate	0.28	0.24	0.32	0.00	rejected
(14b) 3.0% real interest rate	0.28	0.24	0.32	0.00	rejected

*whole:1986Q1-2014Q4,(a):1986Q1-1998Q4,(b):1999Q1-2014Q4

Table 3: Contribution of the US dollar to utility at the sub-sample periods 2(a), 2(b), and 2(c)

	Contribution of dollar(Average)				Welch's t test of (a) and (b)		Welch's t test of (b) and (c)	
Model	whole	(a)	(b)	(c)	p-value	H_0(significance level 99%)	p-value	H_0(significance level 99%)
(13a) 3-month nominal interest rate	0.53	0.57	0.57	0.45	0.97	not rejected	0.00	rejected
(13a) 6-month nominal interest rate	0.54	0.57	0.57	0.46	0.96	not rejected	0.00	rejected
(13b) 1.5% real interest rate	0.54	0.56	0.54	0.51	0.20	not rejected	0.18	not rejected
(13b) 2.0% real interest rate	0.54	0.56	0.53	0.50	0.11	not rejected	0.08	not rejected
(13b) 2.5% real interest rate	0.54	0.56	0.53	0.50	0.05	not rejected	0.04	not rejected
(13b) 3.0% real interest rate	0.53	0.56	0.53	0.50	0.03	not rejected	0.02	not rejected

*whole:1986Q1-2014Q4,(a):1986Q1-1998Q4,(b):1999Q1-2006Q1,(c):2006Q2-2014Q4

Table 4: Contribution of the euro to utility at the sub-sample periods 2(a), 2(b), and 2(c)

	Contribution of euro(Average)				Welch's t test of (a) and (b)		Welch's t test of (b) and (c)	
Model	whole	(a)	(b)	(c)	p-value	H_0(significance level 99%)	p-value	H_0(significance level 99%)
(14a) 3-month nominal interest rate	0.31	0.24	0.33	0.41	0.00	rejected	0.04	not rejected
(14a) 6-month nominal interest rate	0.31	0.24	0.33	0.39	0.00	rejected	0.04	not rejected
(14b) 1.5% real interest rate	0.28	0.24	0.30	0.33	0.00	rejected	0.14	not rejected
(14b) 2.0% real interest rate	0.28	0.24	0.30	0.33	0.00	rejected	0.03	not rejected
(14b) 2.5% real interest rate	0.28	0.24	0.30	0.33	0.00	rejected	0.01	rejected
(14b) 3.0% real interest rate	0.28	0.24	0.30	0.33	0.00	rejected	0.00	rejected

*whole:1986Q1-2014Q4,(a):1986Q1-1998Q4,(b):1999Q1-2006Q1,(c):2006Q2-2014Q4

Table 5: Contribution of the US dollar to utility at the sub-sample periods 3(a), 3(b), and 3(c)

	Contribution of dollar(Average)				Welch's t test of (a) and (b)		Welch's t test of (b) and (c)	
Model	whole	(a)	(b)	(c)	p-value	H_0(significance level 99%)	p-value	H_0(significance level 99%)
(13a) 3-month nominal interest rate	0.53	0.57	0.58	0.42	0.78	not rejected	0.00	rejected
(13a) 6-month nominal interest rate	0.54	0.57	0.58	0.44	0.76	not rejected	0.00	rejected
(13b) 1.5% real interest rate	0.54	0.56	0.54	0.50	0.24	not rejected	0.04	not rejected
(13b) 2.0% real interest rate	0.54	0.56	0.54	0.49	0.12	not rejected	0.01	not rejected
(13b) 2.5% real interest rate	0.54	0.56	0.53	0.49	0.06	not rejected	0.00	rejected
(13b) 3.0% real interest rate	0.53	0.56	0.53	0.49	0.03	not rejected	0.00	rejected

*whole:1986Q1-2014Q4,(a):1986Q1-1998Q4,(b):1999Q1-2007Q2,(c):2007Q3-2014Q4

Table 6: Contribution of the euro to utility at the sub-sample periods 3(a), 3(b), and 3(c)

	Contribution of euro(Average)				Welch's t test of (a) and (b)		Welch's t test of (b) and (c)	
Model	whole	(a)	(b)	(c)	p-value	H_0(significance level 99%)	p-value	H_0(significance level 99%)
(14a) 3-month nominal interest rate	0.31	0.24	0.32	0.43	0.00	rejected	0.00	rejected
(14a) 6-month nominal interest rate	0.31	0.24	0.32	0.41	0.00	rejected	0.00	rejected
(14b) 1.5% real interest rate	0.28	0.24	0.30	0.34	0.00	rejected	0.03	not rejected
(14b) 2.0% real interest rate	0.28	0.24	0.30	0.34	0.00	rejected	0.00	rejected
(14b) 2.5% real interest rate	0.28	0.24	0.30	0.34	0.00	rejected	0.00	rejected
(14b) 3.0% real interest rate	0.28	0.24	0.30	0.34	0.00	rejected	0.00	rejected

*whole:1986Q1-2014Q4,(a):1986Q1-1998Q4,(b):1999Q1-2007Q2,(c):2007Q3-2014Q4

Table 7: Contribution of the US dollar to utility at the sub-sample periods 4(a), 4(b), and 4(c)

	Contribution of dollar(Average)				Welch's t test of (a) and (b)		Welch's t test of (b) and (c)	
Model	whole	(a)	(b)	(c)	p-value	H_0(significance level 99%)	p-value	H_0(significance level 99%)
(13a) 3-month nominal interest rate	0.53	0.57	0.56	0.42	0.88	not rejected	0.00	rejected
(13a) 6-month nominal interest rate	0.54	0.57	0.57	0.43	0.86	not rejected	0.00	rejected
(13b) 1.5% real interest rate	0.54	0.56	0.53	0.50	0.12	not rejected	0.12	not rejected
(13b) 2.0% real interest rate	0.54	0.56	0.53	0.50	0.05	not rejected	0.06	not rejected
(13b) 2.5% real interest rate	0.54	0.56	0.53	0.50	0.02	not rejected	0.03	not rejected
(13b) 3.0% real interest rate	0.53	0.56	0.52	0.49	0.01	rejected	0.02	not rejected

*whole:1986Q1-2014Q4,(a):1986Q1-1998Q4,(b):1999Q1-2008Q2,(c):2008Q3-2014Q4

Table 8: Contribution of the euro to utility at the sub-sample periods 4(a), 4(b), and 4(c)

	Contribution of euro(Average)				Welch's t test of (a) and (b)		Welch's t test of (b) and (c)	
Model	whole	(a)	(b)	(c)	p-value	H_0(significance level 99%)	p-value	H_0(significance level 99%)
(14a) 3-month nominal interest rate	0.31	0.24	0.33	0.44	0.00	rejected	0.01	rejected
(14a) 6-month nominal interest rate	0.31	0.24	0.32	0.41	0.00	rejected	0.01	rejected
(14b) 1.5% real interest rate	0.28	0.24	0.30	0.34	0.00	rejected	0.07	not rejected
(14b) 2.0% real interest rate	0.28	0.24	0.30	0.34	0.00	rejected	0.02	not rejected
(14b) 2.5% real interest rate	0.28	0.24	0.30	0.34	0.00	rejected	0.01	rejected
(14b) 3.0% real interest rate	0.28	0.24	0.30	0.34	0.00	rejected	0.00	rejected

*whole:1986Q1-2014Q4,(a):1986Q1-1998Q4,(b):1999Q1-2008Q2,(c):2008Q3-2014Q4

Table 9: Contribution of the US dollar to utility at the sub-sample periods 5(a), 5(b), and 5(c)

	Contribution of dollar(Average)				Welch's t test of (a) and (b)		Welch's t test of (b) and (c)	
Model	whole	(a)	(b)	(c)	p-value	H_0(significance level 99%)	p-value	H_0(significance level 99%)
(13a) 3-month nominal interest rate	0.53	0.57	0.54	0.43	0.34	not rejected	0.02	not rejected
(13a) 6-month nominal interest rate	0.54	0.57	0.55	0.43	0.42	not rejected	0.01	rejected
(13b) 1.5% real interest rate	0.54	0.56	0.53	0.50	0.10	not rejected	0.10	not rejected
(13b) 2.0% real interest rate	0.54	0.56	0.53	0.50	0.03	not rejected	0.06	not rejected
(13b) 2.5% real interest rate	0.54	0.56	0.52	0.49	0.01	not rejected	0.04	not rejected
(13b) 3.0% real interest rate	0.53	0.56	0.52	0.49	0.00	rejected	0.02	not rejected

*whole:1986Q1-2014Q4,(a):1986Q1-1998Q4,(b):1999Q1-2009Q3,(c):2009Q4-2014Q4

Table 10: Contribution of the euro to utility at the sub-sample periods 5(a), 5(b), and 5(c)

	Contribution of euro(Average)				Welch's t test of (a) and (b)		Welch's t test of (b) and (c)	
whole	All	(a)	(b)	(c)	p-value	H_0(significance level 99%)	p-value	H_0(significance level 99%)
(14a) 3-month nominal interest rate	0.31	0.24	0.35	0.43	0.00	rejected	0.08	not rejected
(14a) 6-month nominal interest rate	0.31	0.24	0.34	0.41	0.00	rejected	0.05	not rejected
(14b) 1.5% real interest rate	0.28	0.24	0.31	0.34	0.00	rejected	0.07	not rejected
(14b) 2.0% real interest rate	0.28	0.24	0.31	0.34	0.00	rejected	0.02	not rejected
(14b) 2.5% real interest rate	0.28	0.24	0.31	0.34	0.00	rejected	0.01	not rejected
(14b) 3.0% real interest rate	0.28	0.24	0.31	0.34	0.00	rejected	0.00	rejected

*whole:1986Q1-2014Q4,(a):1986Q1-1998Q4,(b):1999Q1-2009Q3,(c):2009Q4-2014Q4

Table 11: Average of each term in model (13a')

Model	$(\partial\gamma_t^D/\partial\phi_t^D)d\phi_t^D$	$(\partial\gamma_t^D/\partial i_t^O)di_t^O$	$(\partial\gamma_t^D/\partial i_t^D)di_t^D$
(13a) 3-month nominal interest rate	-0.002	0.004	-0.004
(13a) 6-month nominal interest rate	-0.002	0.005	-0.004

Table 12: Average of each term in model (13b')

Model	$(\partial\gamma_t^D/\partial\phi_t^D)d\phi_t^D$	$(\partial\gamma_t^D/\partial\pi_t^O)d\pi_t^O$	$(\partial\gamma_t^D/\partial\pi_t^D)d\pi_t^D$
(13b) 1.5% real interest rate	-0.002	-0.003	0.028
(13b) 2.0% real interest rate	-0.002	-0.002	0.018
(13b) 2.5% real interest rate	-0.002	-0.001	0.012
(13b) 3.0% real interest rate	-0.002	-0.001	0.009

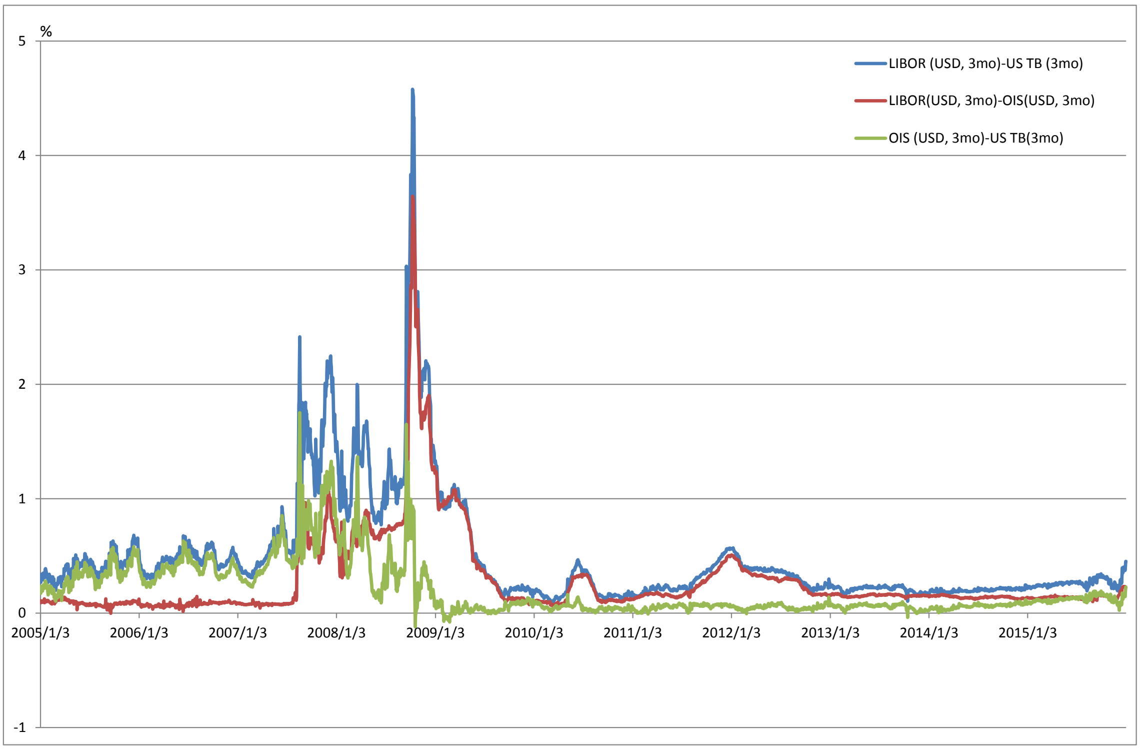
Table 13: Average of each term in model (14a')

Model	$(\partial\gamma_t^E/\partial\phi_t^E)d\phi_t^E$	$(\partial\gamma_t^E/\partial i_t^{O'})di_t^{O'}$	$(\partial\gamma_t^E/\partial i_t^E)di_t^E$
(14a) 3-month nominal interest rate	0.002	0.005	-0.005
(14a) 6-month nominal interest rate	0.002	0.004	-0.005

Table 14: Average of each term in model (14b')

Model	$(\partial\gamma_t^E/\partial\phi_t^E)d\phi_t^E$	$(\partial\gamma_t^E/\partial\pi_t^{O'})d\pi_t^{O'}$	$(\partial\gamma_t^E/\partial\pi_t^E)d\pi_t^E$
(14b) 1.5% real interest rate	0.002	-0.026	0.002
(14b) 2.0% real interest rate	0.002	-0.016	0.001
(14b) 2.5% real interest rate	0.002	-0.011	0.000
(14b) 3.0% real interest rate	0.002	-0.008	0.000

Figure 1: Credit risk premium and liquidity risk premium for US dollar



Data: Datastream

Credit risk = LIBOR minus OIS, liquidity risk = OIS minus US TB

Figure 2a: Domestic currency denominated debt of the euro currency market

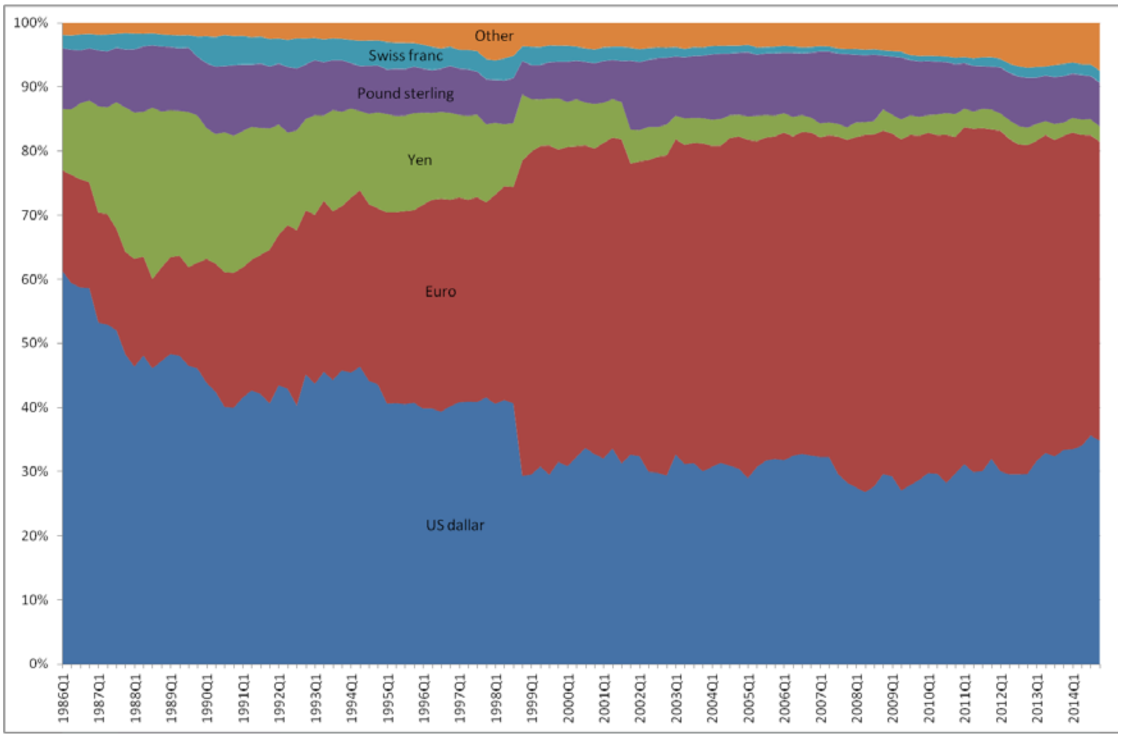


Figure 2b: Foreign currency denominated debt of the euro currency market

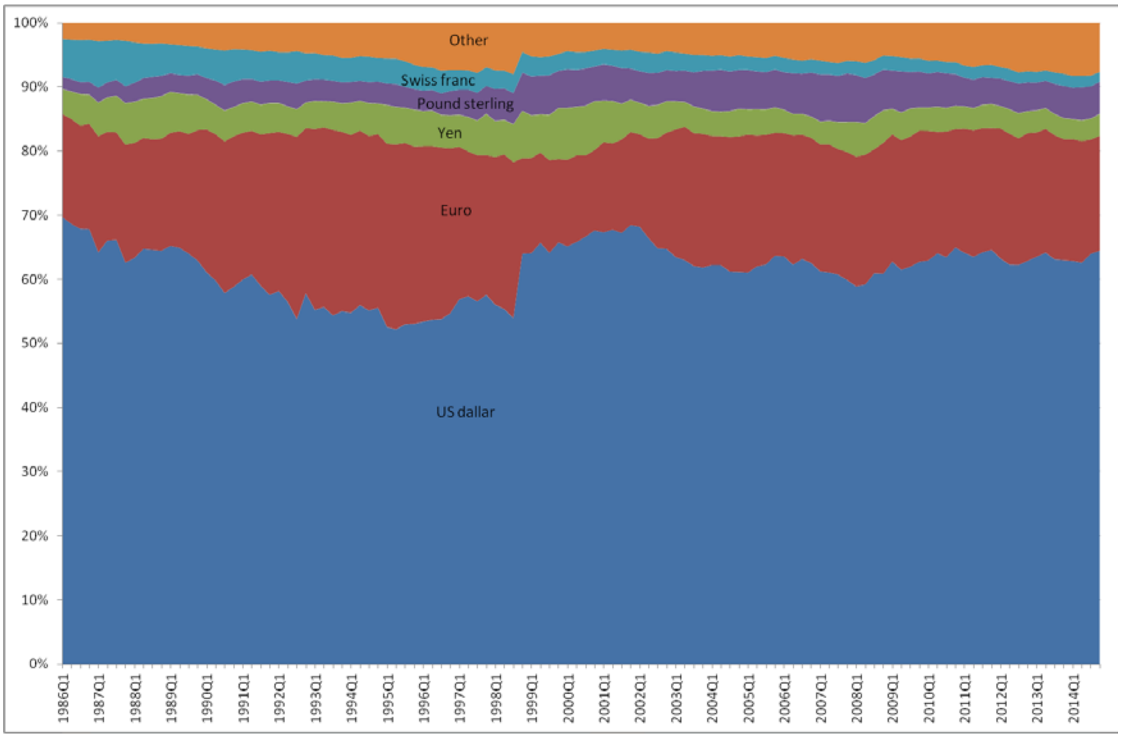


Figure 2c: Total of domestic currency denominated debt and foreign currency denominated debt of the euro currency market

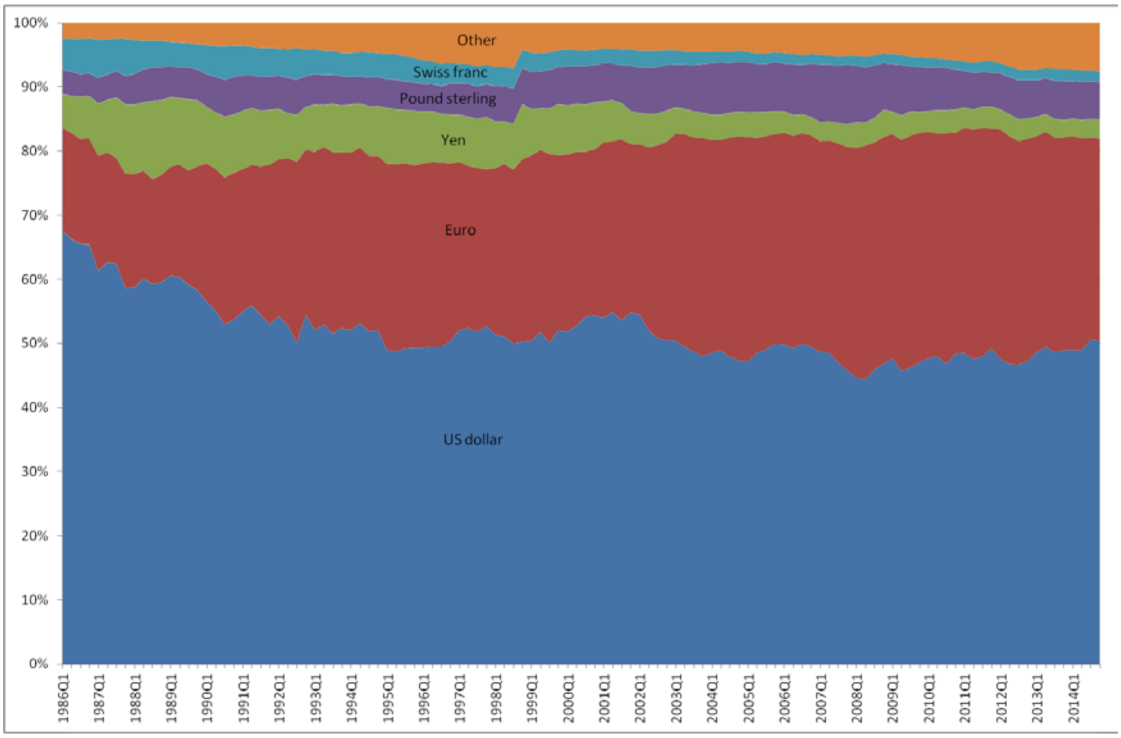


Figure 3a: Contribution of the US dollar to utility in the case of using data on 3-month nominal interest rate in model (13a)

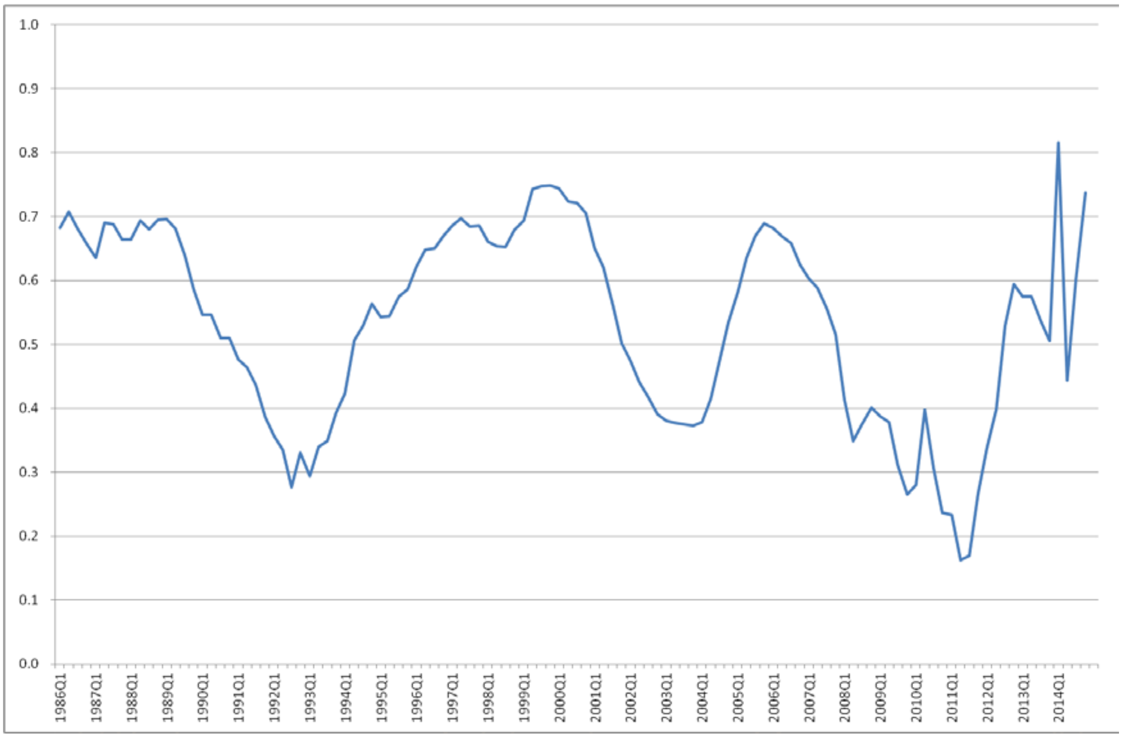


Figure 3b: Contribution of the US dollar to utility in the case of using data on 6-month nominal interest rate in model (13a)

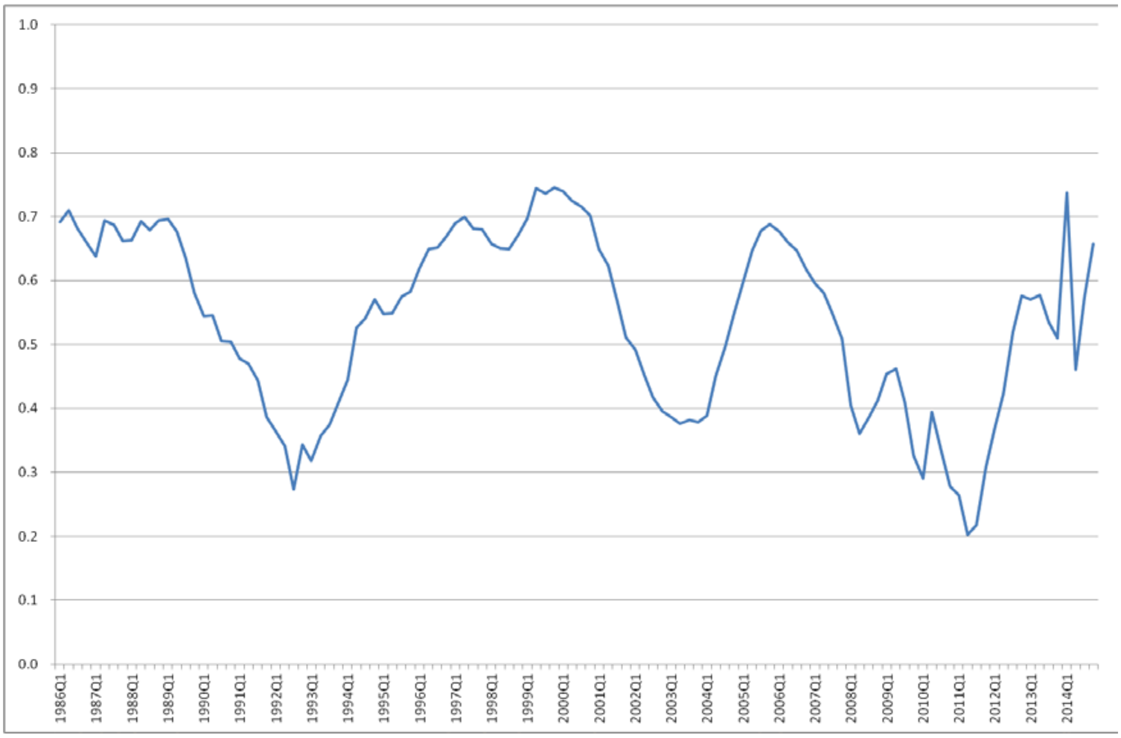
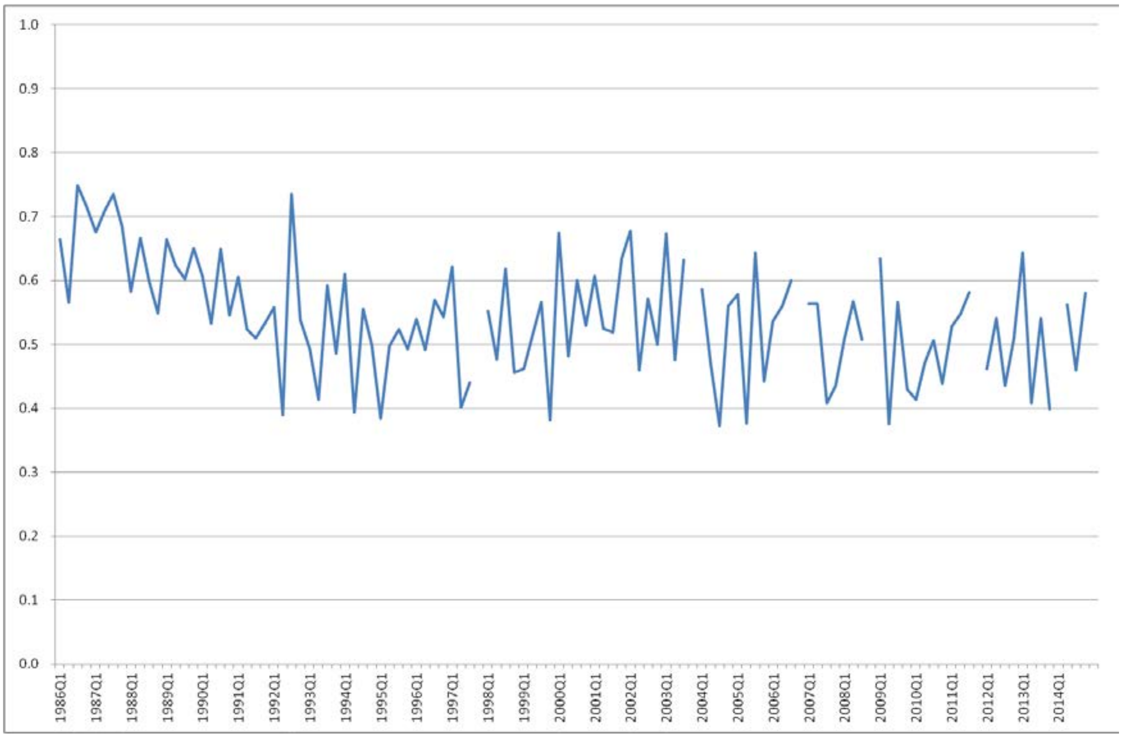
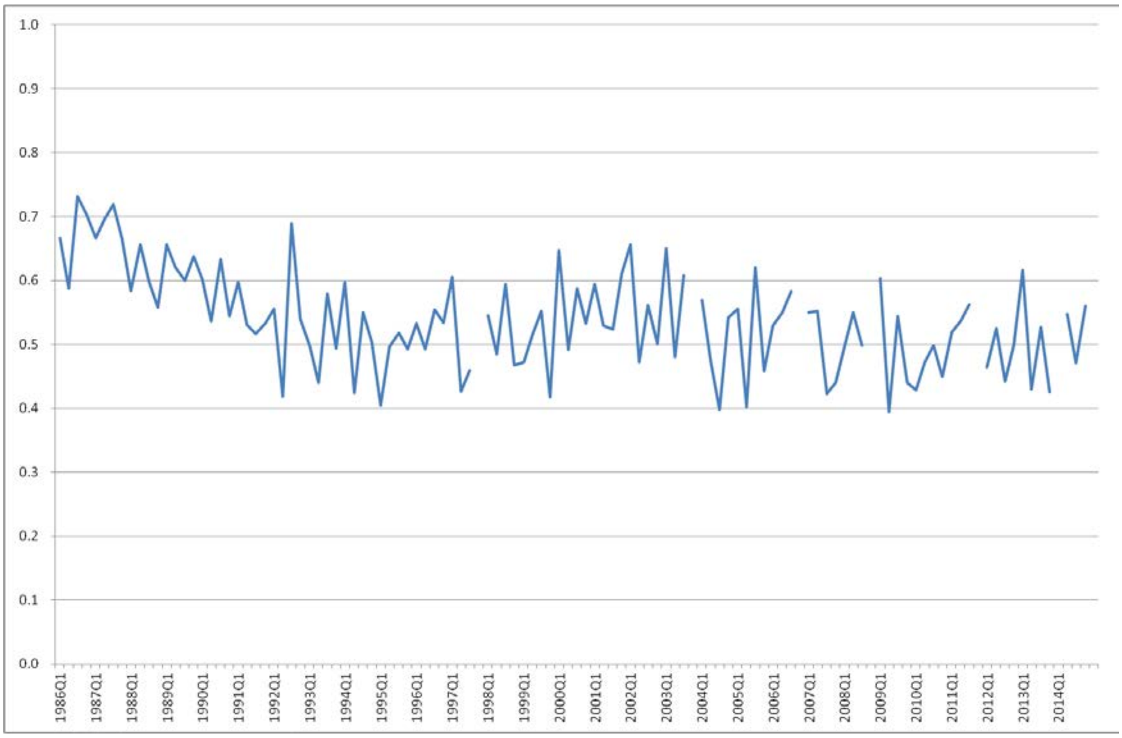


Figure 3c: Contribution of the US dollar to utility in the case of setting 1.5% as a real interest rate in model (13b)



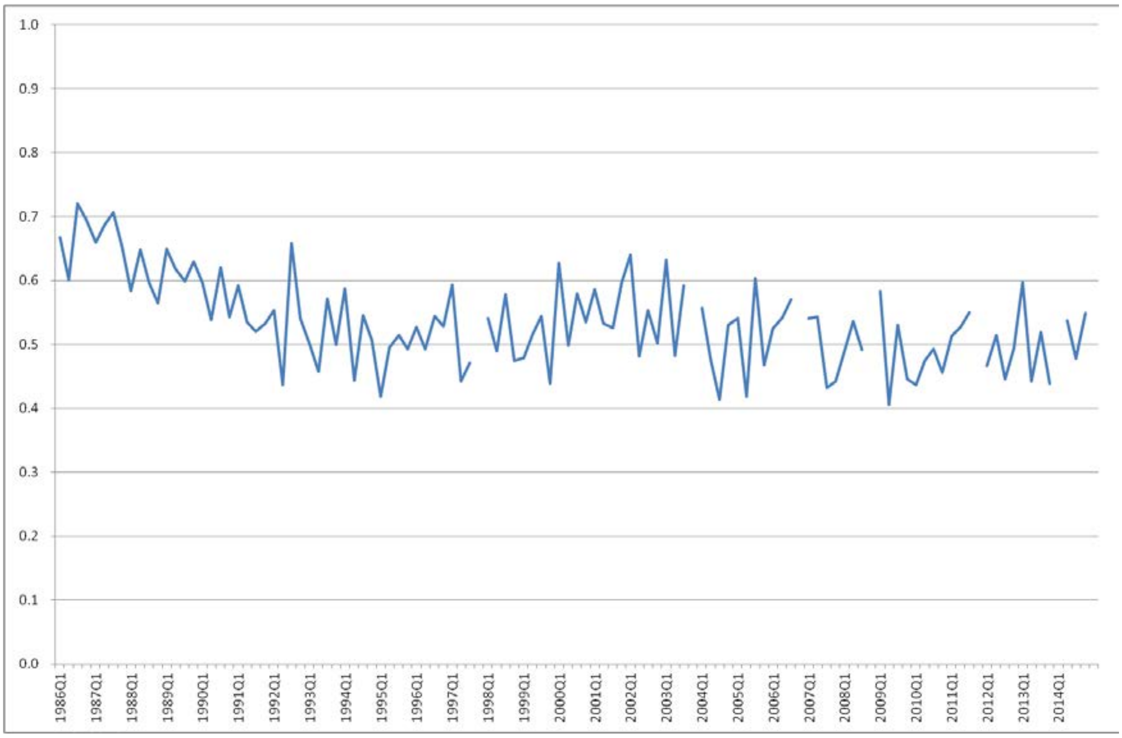
*Outliers which are beyond one times of standard deviation are excluded from our sample.

Figure 3d: Contribution of the US dollar to utility in the case of setting 2.0% as a real interest rate in model (13b)



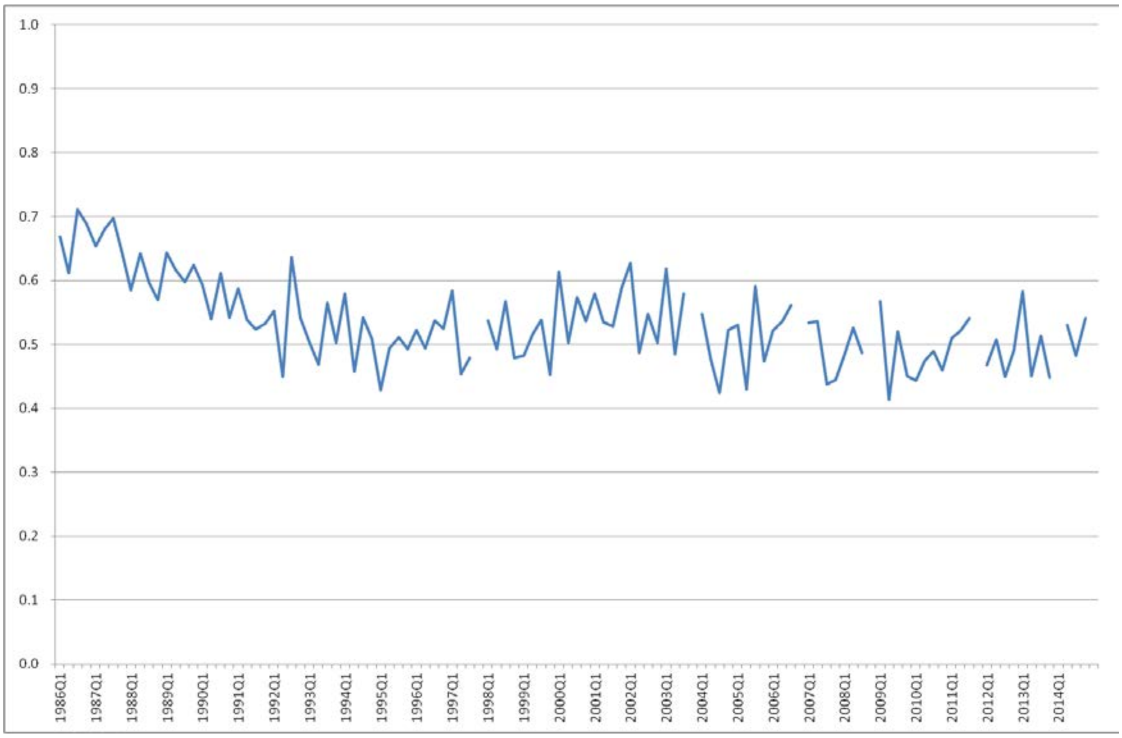
*Outliers which are beyond one times of standard deviation are excluded from our sample.

Figure 3e: Contribution of the US dollar to utility in the case of setting 2.5% as a real interest rate in model (13b)



*Outliers which are beyond one times of standard deviation are excluded from our sample.

Figure 3f: Contribution of the US dollar to utility in the case of setting 3.0% as a real interest rate in model (13b)



*Outliers which are beyond one times of standard deviation are excluded from our sample.

Figure 4a: Contribution of the euro to utility in the case of using data on 3-month nominal interest rate in model (14a)

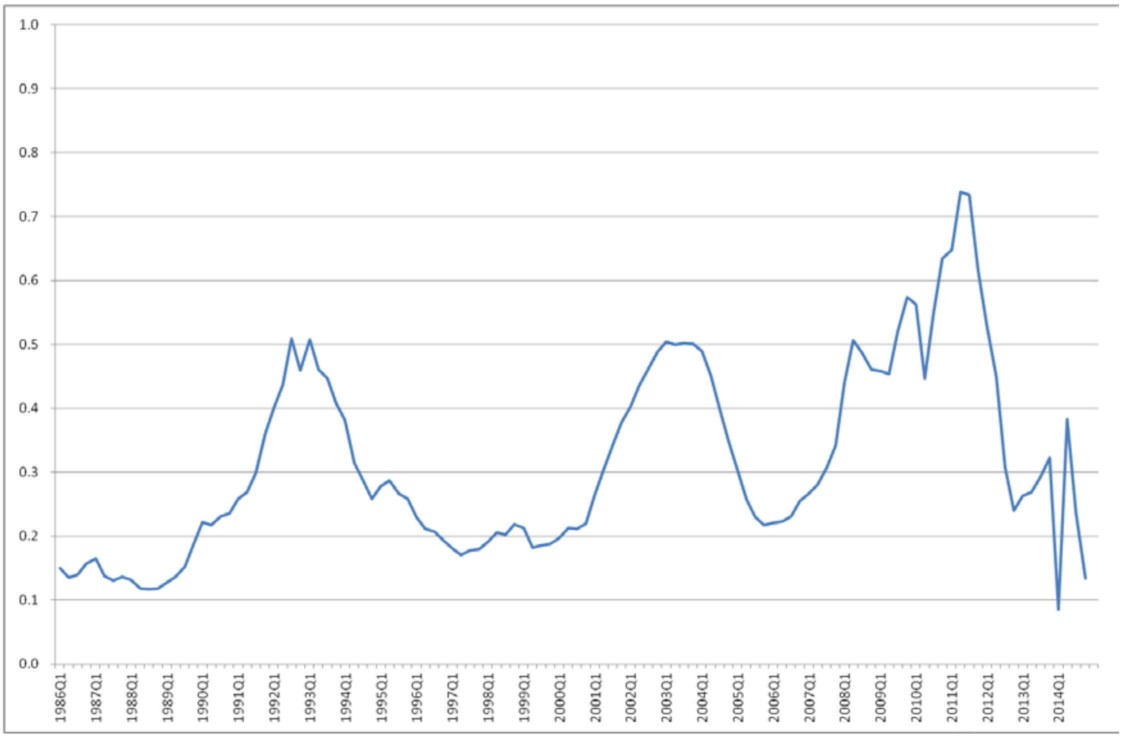


Figure 4b: Contribution of the euro to utility in the case of using data on 6-month nominal interest rate in model (14a)

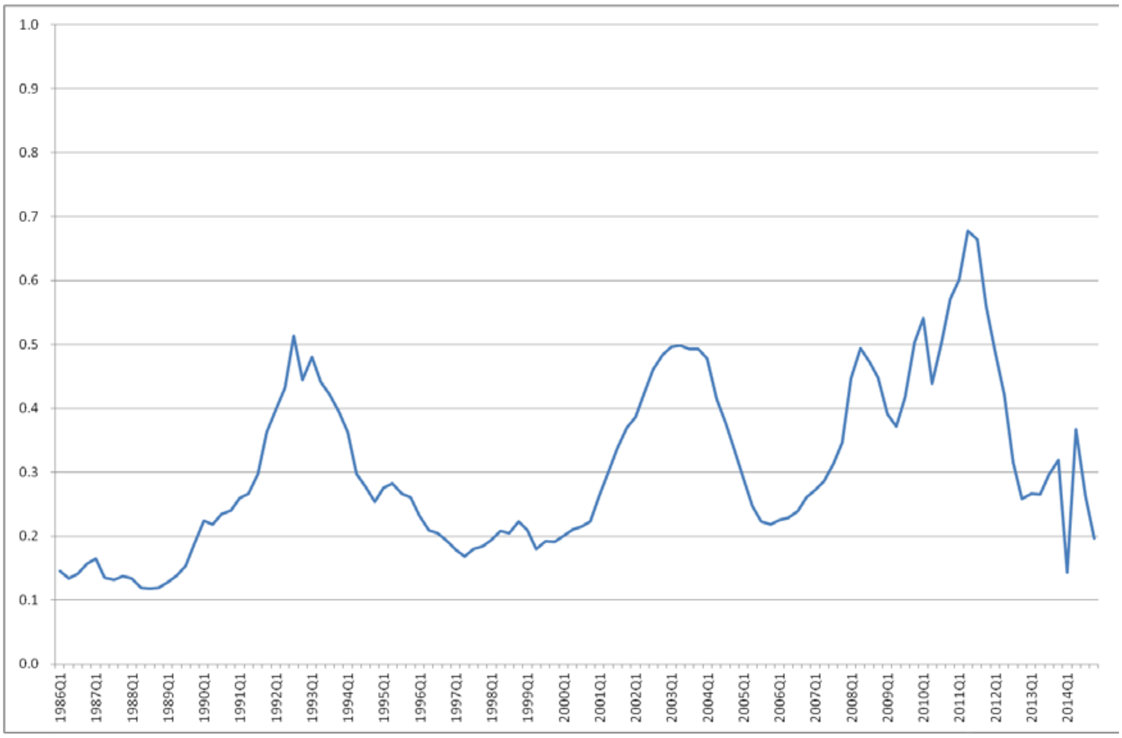
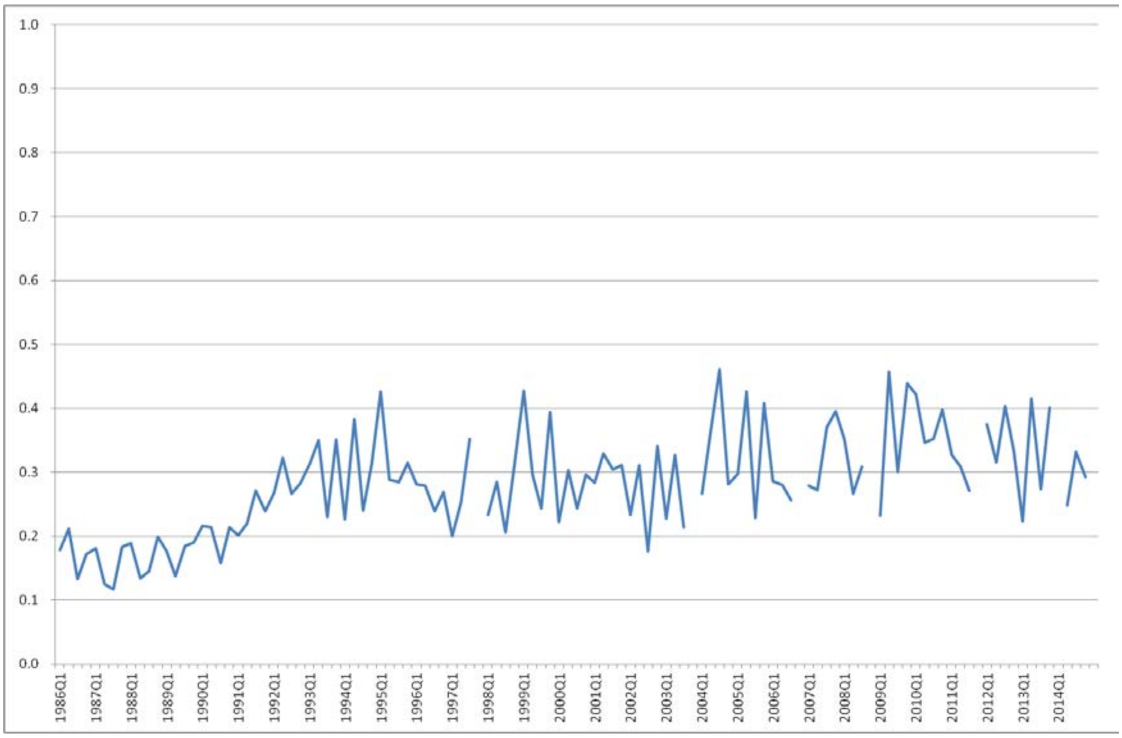
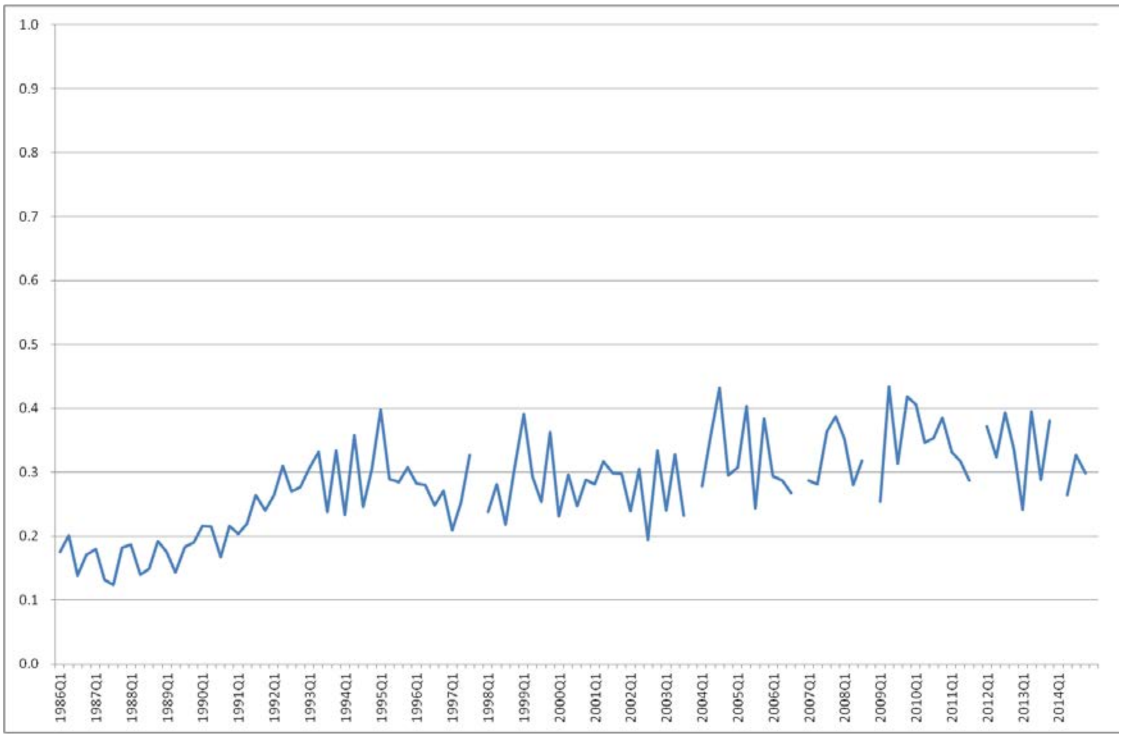


Figure 4c: Contribution of the euro to utility in the case of setting 1.5% as a real interest rate in model (14b)



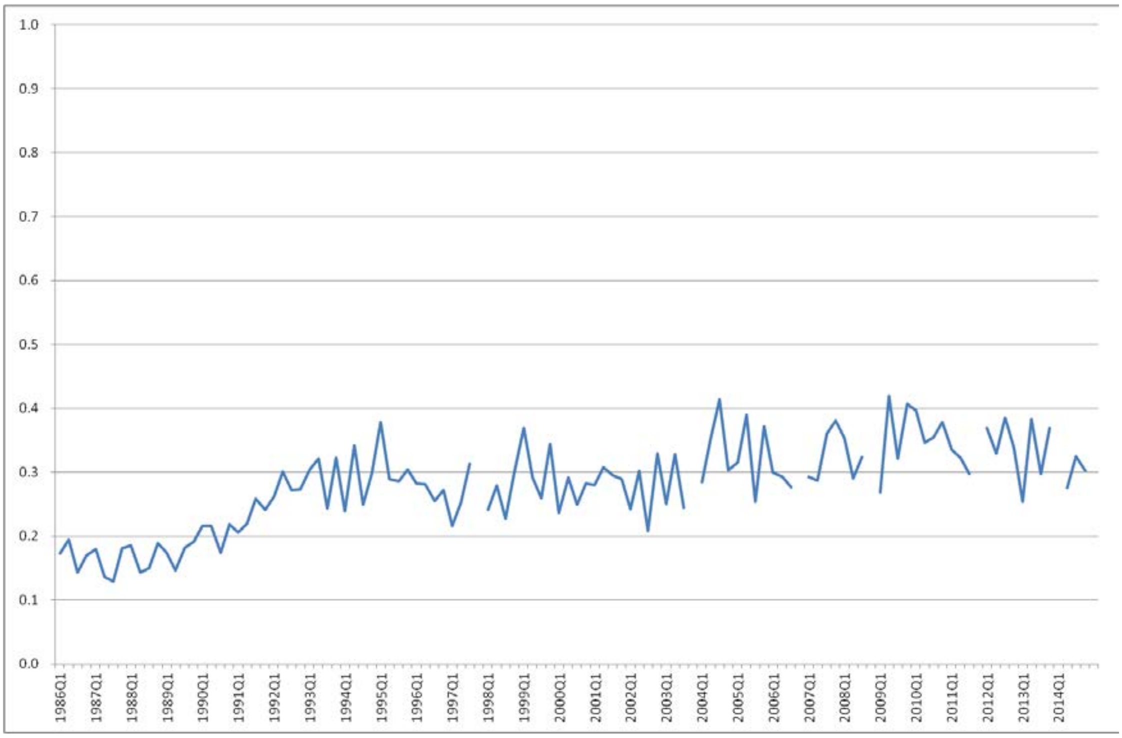
*Outliers which are beyond one times of standard deviation are excluded from our sample.

Figure 4d: Contribution of the euro to utility in the case of setting 2.0% as a real interest rate in model (14b)



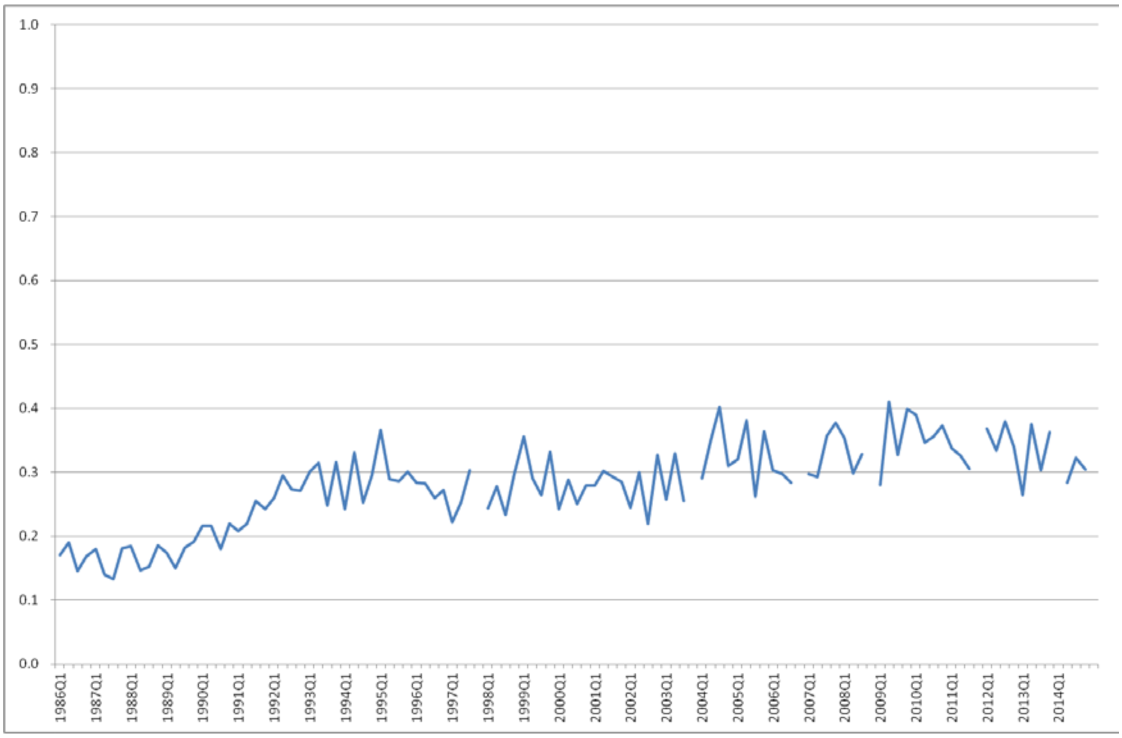
*Outliers which are beyond one times of standard deviation are excluded from our sample.

Figure 4e: Contribution of the euro to utility in the case of setting 2.5% as a real interest rate in model (14b)



*Outliers which are beyond one times of standard deviation are excluded from our sample.

Figure 4f: Contribution of the euro to utility in the case of setting 3.0% as a real interest rate in model (14b)



*Outliers which are beyond one times of standard deviation are excluded from our sample.