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Declining Japanese Yen and Inertia of the U.S. Dollar

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Abstract

The U.S. dollar has maintained its position as the key currency in the global economy even after the euro was introduced to some states of the European Union (EU) in 1999. This is evidence of inertia of the U.S. dollar as the key currency. Our previous study (Ogawa and Muto (2016)) conducted empirical analysis to investigate the effects of several events on the inertia of the U.S. dollar. This paper focuses on the effects of the introduction of the euro and the global financial crisis on the contribution of the Japanese yen to utility. The introduction of the euro significantly decreased the contribution of the Japanese yen to utility as well as that of the Swiss franc. It explains the finding that the introduction of the euro increased the contribution of the euro to utility while the contribution of the U.S. dollar to utility was unchanged. The contribution of the Japanese yen to utility has significantly decreased while the global financial crisis occurred. The Japanese yen has a declining trend in terms of its contribution to utility both before and after the introduction of the euro and the global financial crisis.

Keywords: Japanese yen, Key currency, Inertia, Introduction of the euro, Global financial crisis
JEL Classification Codes: F33, F41, G01

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1. Introduction

Severe shortage of US (United States) dollar liquidity occurred during the global financial crisis from August 2007 to December 2008. It is the current international monetary system with the US dollar as a key currency that is regarded as a background of the US dollar liquidity shortage in the global financial markets. The US dollar liquidity shortage had somewhat an adverse effect on usability or availability of the US dollar. Ogawa and Muto (2016) conducted empirical analysis to show its negative effects on a parameter on holding the US dollar in a utility function. In our previous study, we focused on effects of both the global financial crisis and the euro zone crisis on usability or availability of holding the US dollar in order to clarify whether the US dollar has kept inertia as a key currency through the two crises even though the euro was created as a second key currency in the world economy or a regional key currency in Europe. European Central Bank (2015) reported recent situation regarding a role of the euro as an international currency.

This paper focuses on any effects of the two crises and especially the US dollar liquidity shortage during the global financial crisis on the Japanese yen as well as those on the US dollar and the euro. The Japanese yen is regarded as a major international currency in the international monetary system even though a share of the Japanese yen in euro-currency market is not so large. However, Ito, Koibuchi, Sato, and Shimizu (2013) conducted a questionnaire survey on the choice of invoicing currency with all Japanese manufacturing firms listed in the Tokyo Stock Exchange to show that the Japanese firms use the Japanese yen second to an importing country currency as invoice and trade settlement currencies in exporting products to the United States and Europe. On one hand, Japanese firms tend to use the Japanese yen as invoice and trade settlement currencies in exporting products to Asian countries. A share of Japanese yen-invoicing is larger than 50 percent for almost of destinations for Asian countries. Thus, the Japanese yen is one of the major international currencies especially in Asia.

For our analysis, a money-in-the-utility model is used to take into account both functions as medium of exchange and as store of value of the US dollar in the international currency competition. We focus on a parameter on real balances of the US dollar in a utility function or contribution of the US dollar to utility in the model to analyze empirically how strongly inertia of the US dollar as a key currency works. 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 Japanese yen as well as the US dollar to utility.

In the next section, we explain our theoretical model, that is Sidrauski (1967)-type of money-in-the-utility model, according to Ogawa and Sasaki (1998) and Ogawa and Muto (2016) 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 Japanese yen as well as the Pound sterling and the Swiss franc in utility functions changed after the global financial crisis and the euro zone crisis.

2. A theoretical model[1]

(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.[2]

According to Ogawa and Sasaki (1998), we base on a Sidrauski (1967)-type of money-in-the-utility model[3] 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 a third country. For simplicity, we suppose that the monetary authorities of foreign major countries 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 the monetary authorities in both 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.

[1] This section is cited from a theory part of Ogawa and Muto (2016).
[2] Weil (1991) used a money-in-the-utility model to analyze a parallel currency system while Woodford (1991) used a cash-in-advance model to analyze a parallel currency system. We use a money-in-the-utility model for our analysis given that both of them obtained the same results.
[3] Calvo (1981, 1985), Obstfeld (1981), Blanchard and Fischer (1989).

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[4] and illiquidity costs[5] 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 and O, and bonds in currencies D and O.

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

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

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

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

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

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

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 means 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 means 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:

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

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

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.

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

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 ($f_t = \bar{f}$). 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 $\bar{\mu}^A$.

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

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

(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:

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

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:

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

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

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:

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

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

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

From equations (10) and (11), the optimal composition ratio of international currencies and the optimal 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 optimal 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 a currency to utility

Here we suppose that international currencies include the US dollar, the euro, the Japanese yen, the Pound sterling, and the Swiss franc in order to analysis contributions of the Japanese yen, the Pound sterling, and the Swiss franc to utility as well as those of the US dollar and the euro. According to the above mentioned theoretical model, a model for estimating a share of the US dollar is as follows.

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

where ϕ_t^D : a share of the US dollar in period *t*, m_t^D : a real balance of the US dollar held by the private sector in period *t*, m_t^O is real balances of other international currencies (the euro, the Japanese yen, the Pound sterling, and the Swiss franc) held by the private sector 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, the Japanese yen, the Pound sterling, and the Swiss franc) 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, Japan, the United kingdom, and Switzerland) 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, the Japanese yen, the Pound sterling, and the Swiss franc are as follows, respectively:

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

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

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

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

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

We use equations (12a), (12b), (12c), (12d), and (12e) to estimate the parameters γ_t^D, γ_t^E, γ_t^Y, γ_t^P, and γ_t^S which indicates the degree of contribution of the US dollar, the euro, the Japanese yen, the Pound sterling, and the Swiss franc to utility, respectively.

The contribution of the US dollar to utility γ_t^D is transformed from equations (12a) into the following equations:

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

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

Similarly, the contribution of the euro to utility γ_t^E is transformed from equations (12b) into the following equations:

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

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

The contribution of the Japanese yen to utility γ_t^Y is transformed from equations (12c) into the following equations:

$$\gamma_t^Y = \frac{1}{1+\left(\frac{1}{\phi_t^Y}-1\right)\frac{i_t^{O^{**}}}{i_t^Y}} \tag{15a}$$

$$\gamma_t^Y = \frac{1}{1+\left(\frac{1}{\phi_t^Y}-1\right)\frac{\pi_t^{O^{**}}+\bar{r}}{\pi_t^Y+\bar{r}}} \tag{15b}$$

The contribution of the Pound sterling to utility γ_t^P is transformed from equations (12d) into the following equations:

$$\gamma_t^P = \frac{1}{1+\left(\frac{1}{\phi_t^P}-1\right)\frac{i_t^{O^{***}}}{i_t^P}} \tag{16a}$$

$$\gamma_t^P = \frac{1}{1+\left(\frac{1}{\phi_t^P}-1\right)\frac{\pi_t^{O^{***}}+\bar{r}}{\pi_t^P+\bar{r}}} \tag{16b}$$

The contribution of the Swiss franc to utility γ_t^S is transformed from equations (12e) into the following equations:

$$\gamma_t^S = \frac{1}{1+\left(\frac{1}{\phi_t^S}-1\right)\frac{i_t^{O^{****}}}{i_t^S}} \tag{17a}$$

$$\gamma_t^S = \frac{1}{1+\left(\frac{1}{\phi_t^S}-1\right)\frac{\pi_t^{O^{****}}+\bar{r}}{\pi_t^S+\bar{r}}} \tag{17b}$$

In this paper, we use the models (13a), (14a), (15a), (16a), and (17a) to conduct empirical analysis of estimating contributions of the US dollar, the euro, the Japanese yen, the Pound sterling, and the Swiss franc to utility by using data on 3-month or 6-month nominal interest rate. In addition, we use the models (13b), (14b), (15b), (16a), and (17a) to conduct empirical analysis of estimating contributions of the US dollar, the euro, the Japanese yen, the Pound sterling, and the Swiss franc to utility by setting 1.5%, 2.0%, 2.5%, or 3.0% as a real interest rate[6]. Since the nominal interest rate is fluctuating sharply, the models (13a), (14a), (15a), (16a), and (17a) is fluctuating sharply. By contrast, the models (13b), (14b), (15a), (16a), and (17a) is stable because the expected inflation

[6] 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.

rate is relatively stable and the real interest rate is fixed. We thought that only the models (13a), (14a), (15a), (16a), and (17a) of fluctuating sharply cannot be obtained robustness result. Therefore, we also analyzed the stable models (13b), (14b), (15b), (16b), and (17b).

(2) Movements in liquidity risk premium

We should watch movements in liquidity situation in financial markets, especially interbank markets, during sample period before we set analytical periods. We use data on liquidity risk premium to identify liquidity situation.

Figure 1a 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[7] with other major central banks to provide US dollar liquidity to other countries.

Figure 1b shows movements in three spreads of LIBOR (euro, 3 months) minus yields on German treasury discount paper (Bubills) (EUR TB rate) (euro, 3 months), LIBOR (euro, 3 months) minus OIS rate (euro, 3 months), and OIS rate (euro, 3 months) minus EUR TB rate (euro, 3 months). Figure 1c shows movements in three spreads of LIBOR (JPY, 3 months) minus yields on Japanese Treasury Discount Bills (JPY TB rate) (JPY, 3 months), LIBOR (JPY, 3 months) minus OIS rate (JPY, 3 months), and OIS rate (JPY, 3 months) minus JPY TB rate (JPY, 3 months). Figure 1d shows movements in three

[7] 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.

spreads of LIBOR (GBP, 3 months) minus Yields on UK Government bonds (gilts) (GBP TB rate) (GBP, 3 months), LIBOR (GBP, 3 months) minus OIS rate (GBP, 3 months), and OIS rate (GBP, 3 months) minus GBP TB rate (GBP, 3 months). Figure 1e shows movements in three spreads of LIBOR (CHF, 3 months) minus Yields on Switzerland Government bond (CHF TB rate) (CHF, 3 months), LIBOR (CHF, 3 months) minus OIS rate (CHF, 3 months), and OIS rate (CHF, 3 months) minus CHF TB rate (CHF, 3 months). These figures show a common characteristics that liquidity risk premium for each of the currencies show no increase during the period from 2007 to 2008 though only liquidity risk premium for the euro jumped at the Lehman Brothers bankruptcy. The stable movements in the liquidity risk premium for the currencies is different those for the US dollar.

(3) Analytical periods

A whole sample period covers a period from 1986Q1 to 2016Q2 [8] due to data availability. 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 2016Q2. 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 housing bubble burst 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 2016Q2. We call these sub-sample periods as sub-sample periods 2(a), 2(b), and 2(c). The US housing bubble burst 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 US housing bubble burst on contribution of the US dollar and the euro to utility.

Figure 1a shows that financial institutions in Europe had faced liquidity shortage since the BNP Paribas shock happened in August 2007. 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

[8] In Ogawa and Muto (2016), a whole sample period covered from 1986Q1 to 2014Q4. In this paper, we extend the whole sample period into 2016Q2.

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 2016Q2. 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 2016Q2. 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 2016Q2. 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.

(4) Data

The shares of the US dollar, the euro, the Japanese yen, the Pound sterling, and the Swiss franc 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 denominated debts and foreign currency denominated debts in the euro currency markets as nominal balances of the relevant currency or a numerator of m_t^D. The data are obtained from a website of BIS (Bank for International Settlements). 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 and 2b. 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 2b shows movements in shares of all 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.

We use 3-month LIBOR and 6-month LIBOR data as the nominal interest rate. The data are obtained from a website of International Financial Statistics (IMF). Each of i_t^O, $i_t^{O^*}$, $i_t^{O^{**}}$, $i_t^{O^{***}}$, and $i_t^{O^{****}}$ is a weighted average of nominal interest rates in terms of four other currencies for the US dollar, the euro, the Japanese yen, the Pound sterling, and the Swiss franc 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 a website of 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 twenty eight years to estimate an ARIMA model. The BIC 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 a website of Organisation for Economic Co-operation and Development (OECD).

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[9].

(5) Analytical method

We conduct point estimation for parameters or contributions of the US dollar, the euro, the Japanese yen, the Pound sterling, and the Swiss franc to utility in each period. Based on the point estimation, we calculate a mean value of the contribution in 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 H_0 is not rejected, it is regarded to be not statistically significant that the contribution of the currency change over time between the relevant sub-sample periods. If the null hypothesis H_0 is rejected and the mean value increases (decreases), it is regarded to be statistically significant that 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.

(6) Analytical results

Time series of contribution of the US dollar to utility are shown in Figures 3a to 3f. Time series of contribution of the euro to utility are shown in Figures 4a to 4f. Time series of contribution of the Japanese yen to utility are shown in Figures 5a to 5f. Time series of contribution of the Pound sterling to utility are shown in Figures 6a to 6f. Time

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9 See Feenstra, Inklaar, and Timmer (2015) for reference.

series of contribution of the Swiss franc to utility are shown in Figures 7a to 7f.

We conduct the above-mentioned point estimation for the contributions of the US dollar, the euro, the Japanese yen, the Pound sterling, and the Swiss franc to utility from 1986Q1 to 2016Q2. We exclude results of point estimation which are regarded as outliers because they exceed plus/minus three times of standard deviation from its estimation.

Table 1 shows empirical results of the contribution of the US dollar to utility in 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 0.476-0.574. On the other hand, means of the contribution of the US dollar to utility after the introduction of euro are 0.387-0.521.

Row of "Welch's t test of (a) and (b)" shows p-values of the Welch's t test and rejection of the hypothesis that means significantly equal between sub-sample periods (a) and (b) at the 99% level. 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 all of the models. It implies that the contribution of the US dollar to utility has changed before and after the introduction of the euro. The contribution has been stable at 0.426-0.544 in the whole sample period.

Table 2 shows analytical results of the contribution of the euro to utility in the sub-sample periods 1(a) and 1(b). The contribution of the euro to utility is 0.214-0.229 before the introduction of the euro. That is 0.314-0.338 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 Japanese yen to utility in the sub-sample periods 1(a) and 1(b). The contribution of the Japanese yen to utility is 0.059-0.093 before the introduction of the euro. That is 0.009-0.037 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 Japanese yen to utility has made statistically significant change before and after the introduction of the euro.

Table 4 shows analytical results of the contribution of the Pound sterling to utility in the sub-sample periods 1(a) and 1(b). The contribution of the Pound sterling to utility is 0.046-0.066 before the introduction of the euro. That is 0.066-0.111 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 Pound sterling to utility has made statistically significant change before and after the introduction of the euro.

Table 5 shows analytical results of the contribution of the Swiss franc to utility in the sub-sample periods 1(a) and 1(b). The contribution of the Swiss franc to utility is 0.030-0.037 before the introduction of the euro. That is 0.005-0.017 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 Swiss franc to utility has made statistically significant change before and after the introduction of the euro.

Table 6 shows analytical results of the contribution of the US dollar to utility in the sub-sample periods 2(a), 2(b), and 2(c). The three sub-sample periods are divided to focus on effects of the US housing bubble burst as well as the introduction of the euro. The contribution of the US dollar to utility is 0.476-0.574 in the sub-sample period (a) or before the introduction of the euro. The contribution of the US dollar to utility is 0.430-0.552 in the sub-sample period (b) or before the US housing bubble burst (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 in models (13a) and the cases of setting 1.5% and 2.0% as a real interest rate in the models (13b). On one hand, 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 in the cases of setting 2.5% and 3.0% as a real interest rate in the models (13b).

Column (c) shows that the contribution of the US dollar to utility is 0.354-0.498 after the US housing bubble burst. 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 (13a). It implies that the contribution of the US dollar to utility has not changed before and after the US housing bubble burst. 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 (13b). Throughout the whole of sample period, the contribution of the US dollar to utility has been stable at 0.426-0.544 for all of models.

Table 7 shows analytical results of the contribution of the euro to utility in the sub-sample periods 2(a), 2(b), and 2(c). The contribution of the euro is 0.214-0.229 before the introduction of euro. The contribution of the euro to utility before the US housing bubble burst (after the introduction of the euro) is 0.292-0.311. 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 in all of the models. It implies that the contribution of the euro to utility has increased before the US housing bubble burst. The contribution of the euro to utility is 0.330-0.357 after the US housing bubble burst. 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 (14b). It implies that we obtained mixed analytical results regarding effects of the US housing bubble burst on the contribution of the euro to utility.

Table 8 shows analytical results of the contribution of the Japanese yen to utility in the sub-sample periods 2(a), 2(b), and 2(c). The contribution of the Japanese yen is 0.059-0.093 before the introduction of euro. The contribution of the Japanese yen to utility before the US housing bubble burst (after the introduction of the euro) is 0.002-0.046. 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 in all of the models. It implies that the contribution of the Japanese yen to utility has decreased before the US housing bubble burst. The contribution of the Japanese yen to utility is 0.013-0.031 after the US housing bubble burst. 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 all of the models except for in the case of using data on 1.5% real interest rate in the model (15b). However, the contribution of the Japanese yen to utility significantly increased before and after the US housing bubble burst in the models (15a) while it significantly decreased in the models (15b). We obtained mixed analytical results regarding effects of the US housing bubble burst on the contribution of the Japanese yen to utility.

Table 9 shows analytical results of the contribution of the Pound sterling to utility in the sub-sample periods 2(a), 2(b), and 2(c). The contribution of the Pound sterling is 0.046-0.066 before the introduction of euro. The contribution of the Pound sterling to utility before the US housing bubble burst (after the introduction of the euro) is 0.059-0.111. 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 in all of the models. It implies that the contribution of the Pound sterling to utility has increased before the US housing bubble burst. The contribution of the Pound sterling to utility is 0.068-0.111 after the US housing bubble burst. 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 all of the models. It implies that the contribution of the Pound sterling has not changed over time before the US housing bubble burst.

Table 10 shows analytical results of the contribution of the Swiss franc to utility in the sub-sample periods 2(a), 2(b), and 2(c). The contribution of the Swiss franc is 0.030-0.037 before the introduction of euro. The contribution of the Swiss franc to utility before the US housing bubble burst (after the introduction of the euro) is 0.009-0.020. 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 in all of the models. It implies that the contribution of the Swiss franc to utility has decreased before the US housing bubble burst. The contribution of the Swiss franc to utility is 0.001-0.014 after the US housing bubble burst. 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 all of the models. It implies that the contribution of the Swiss franc has changed over time before the US housing bubble burst.

Table 11 shows analytical results of the contribution of the US dollar to utility in 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 0.476-0.574 before the introduction of euro. Column (b) shows the contribution of the US dollar to utility is 0.436-0.549 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 except for in the case of using data on 2.5% and 3.0% real interest rate in the model (15b). It implies that the contribution of the US dollar to utility has not changed over time before the BNP Paribas shock though the hypothesis is rejected in the case of setting 2.5% and 3.0% as a real interest rate in the model (13b).

Column (c) shows that the contribution of the US dollar to utility is 0.336-0.495 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 all of the models except for in the case of using data on 6-month interest rate in the model (13a).

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 0.336-0.495. 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 case of using data on 6-month nominal interest rate in the model (13a). We obtained mixed analytical results regarding effects of the BNP Paribas shock on the contribution of the US dollar to utility.

Table 12 shows analytical results of the contribution of the euro to utility in 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 euro to utility. The contribution of the euro to utility is about 0.214-0.229 before the introduction of the euro. The contribution of the euro to utility is 0.296-0.302 before the BNP Paribas shock and 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 0.328-0.373 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 not rejected in models (14a) and the case of using data on 2.0% real interest rate in the model (14b). We obtained mixed analytical results regarding effects of the BNP Paribas shock on the contribution of the euro to utility.

Table 13 shows analytical results of the contribution of the Japanese yen to utility in 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 Japanese yen to utility. The contribution of the Japanese yen to utility is about 0.059-0.093 before the introduction of the euro. The contribution of the Japanese yen to utility is 0.002-0.043 before the BNP Paribas shock and 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 Japanese yen to utility had decreased before and after the introduction of the euro before BNP Paribas shock. The contribution of the Japanese yen to utility is 0.015-0.032 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 (15b). The contribution of the Japanese yen to utility has decreased after the BNP Paribas shock in the case of setting 2.0%, 2.5%, and 3.0% as a real interest rate in the model (15b) while it increased after the BNP Paribas shock at models (15a).

Table 14 shows analytical results of the contribution of the Pound sterling to utility in the sub-sample periods 3(a), 3(b), and 3(c). The contribution of the Pound sterling is 0.046-0.066 before the introduction of euro. The contribution of the Pound sterling to utility before the BNP Paribas shock (after the introduction of the euro) is 0.061-0.107. 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 in all of the models. It implies that the contribution of the Pound sterling to utility has increased before the BNP Paribas shock. The contribution of the Pound sterling to utility is 0.067-0.113 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 not rejected in all of the models. It implies that the contribution of the Pound sterling has not changed over time before the BNP Paribas shock.

Table 15 shows analytical results of the contribution of the Swiss franc to utility in the sub-sample periods 3(a), 3(b), and 3(c). The contribution of the Swiss franc is 0.030-0.037 before the introduction of euro. The contribution of the Swiss franc to utility before the BNP Paribas shock (after the introduction of the euro) is 0.009-0.019. 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 in all of the models. It implies that the contribution of the Swiss franc to utility has decreased before the BNP Paribas shock. The contribution of the Swiss franc to utility is 0.000-0.014 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 all of the models. It implies that the contribution of the Swiss franc has changed over time before the BNP Paribas shock.

Table 16 shows results of analysis of the contribution of the US dollar to utility in 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 0.476-0.574 before the introduction of the euro. The contribution of the US dollar to utility is 0.424-0.543 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 in models (13a). On one hand, 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 in models (13b).

The contribution of the US dollar to utility is 0.337-0.496 after the Lehman Brothers bankruptcy. 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 in models (13a). On one hand, 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 in models (13b). We obtained mixed analytical results regarding effects of the Lehman Brothers bankruptcy on the contribution of the US dollar to utility.

Table 17 shows results of analysis of the contribution of the euro to utility in 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 0.214-0.229 before the introduction of the euro to utility. The contribution of the euro to utility is 0.303-0.311 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 in 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 0.327-0.371 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 at all of 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 Lehman Brothers bankruptcy.

Table 18 shows results of analysis of the contribution of the Japanese yen to utility in 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 Japanese yen to utility is 0.059-0.093 before the introduction of the euro to utility. The contribution of the Japanese yen to utility is 0.003-0.042 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 in all of the models. It implies that the introduction of the euro decreased the contribution of the Japanese yen to utility before the Lehman Brothers bankruptcy.

The contribution of the Japanese yen to utility is 0.015-0.032 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 all of the models except for the cases of setting 1.5% as a real interest rate in the model (15b). It implies that the contribution of the Japanese yen to utility has changed before and after the Lehman Brothers bankruptcy.

Table 19 shows analytical results of the contribution of the Pound sterling to utility in the sub-sample periods 4(a), 4(b), and 4(c). The contribution of the Pound sterling is

0.046-0.066 before the introduction of euro. The contribution of the Pound sterling to utility before the Lehman Brothers bankruptcy (after the introduction of the euro) is 0.063-0.110. 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 in all of the models. It implies that the contribution of the Pound sterling to utility has increased before the Lehman Brothers bankruptcy. The contribution of the Pound sterling to utility is 0.065-0.111 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 all of the models. It implies that the contribution of the Pound sterling has not changed over time before and after the Lehman Brothers bankruptcy.

Table 20 shows analytical results of the contribution of the Swiss franc to utility in the sub-sample periods 4(a), 4(b), and 4(c). The contribution of the Swiss franc is 0.030-0.037 before the introduction of euro. The contribution of the Swiss franc to utility before the Lehman Brothers bankruptcy (after the introduction of the euro) is 0.009-0.018. 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 in all of the models. It implies that the contribution of the Swiss franc to utility has decreased before the Lehman Brothers bankruptcy. The contribution of the Swiss franc to utility is -0.002-0.015 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 all of the models. It implies that the contribution of the Swiss franc has changed over time before and after the Lehman Brothers bankruptcy.

Table 21 shows results of analysis of the contribution of the US dollar to utility in 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 0.476-0.574 before the introduction of euro. The contribution of the US dollar to utility is 0.406-0.536 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 rejected at all the models. It implies that the introduction of the euro changed the contribution of US dollar before the Greek debt crisis.

The contribution of the US dollar to utility is 0.352-0.498 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 in models (13a) and the case of using data on 3.0% real interest rate in the model (13b). We obtained mixed analytical results regarding effects of the Greek debt on the contribution of the US dollar to utility.

Table 22 shows results of analysis of the contribution of the euro to utility in 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 0.214-0.229 before the introduction of the euro. The contribution of the euro to utility is 0.308-0.330 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 0.322-0.352 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. It implies that the contribution of the euro to utility has not changed before and after the Greek debt crisis.

Table 23 shows results of analysis of the contribution of the Japanese yen to utility in 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 Japanese yen to utility is 0.059-0.093 before the introduction of the euro. The contribution of the Japanese yen to utility is 0.005-0.042 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 decreased the contribution of the Japanese yen to utility before the Greek debt crisis.

The contribution of the Japanese yen to utility is 0.015-0.030 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 rejected at all the models except for the case of setting 1.5% as a real interest rate in the model (15b). It implies that the contribution of the Japanese yen to utility has changed before and after the Greek debt crisis though the hypothesis is not rejected in the one case. However, movements in the contribution of the Japanese yen to utility significantly increased before and after the Greek debt crisis in the models (15a) were regarded to be abnormal because those were 0.005 in the sub-sample period (b). On the other hand, in the cases of using real interest rate data, the contributions of the Japanese yen to utility decreased from 0.039-0.042 during a period from the introduction of the euro to two crises to 0.029-0.030 through the two crises.

Table 24 shows analytical results of the contribution of the Pound sterling to utility in the sub-sample periods 5(a), 5(b), and 5(c). The contribution of the Pound sterling is 0.046-0.066 before the introduction of euro. The contribution of the Pound sterling to utility before the Greek debt crisis (after the introduction of the euro) is 0.064-0.110. 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 in all of the models. It implies that the contribution of the Pound sterling to utility has increased before the Greek debt crisis. The contribution of the Pound sterling to utility is 0.063-0.111 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 in all of the models. It implies that the contribution of the Pound sterling has not changed over time before and after the Greek debt crisis.

Table 25 shows analytical results of the contribution of the Swiss franc to utility in the sub-sample periods 5(a), 5(b), and 5(c). The contribution of the Swiss franc is 0.030-0.037 before the introduction of euro. The contribution of the Swiss franc to utility before the Greek debt crisis (after the introduction of the euro) is 0.009-0.018. 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 in all of the models. It implies that the contribution of the Swiss franc to utility has decreased before the Lehman Brothers bankruptcy. The contribution of the Swiss franc to utility is -0.004-0.014 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 rejected in all of the models except for the case of setting 1.5% as a real interest rate in the model (17b). It implies that the contribution of the Swiss franc has changed over time before and after the Greek debt crisis though the hypothesis is not rejected in the case of setting 1.5% as a real interest rate in the model (17b).

(7) Summary of analytical results

It is clear that contribution of the euro to utility increased after the introduction of the euro while that of the Japanese yen as well as the Swiss franc decreased. In addition, the contribution of Pound sterling to utility increased after the introduction of the euro. On one hand, results of contribution of the US dollar significantly decreased after the introduction of the euro. When we take into account the crises to conduct empirical analyses on effects of the introduction of euro on contribution of the US dollar to utility, it has not changed before and after the introduction of the euro in many cases. As Ogawa and Muto (2016) pointed out, the reason is regarded to be that the latter sub-sample period includes effect of the global financial crisis. On one hand, contributions of the euro, the Swiss franc, and the Japanese yen to utility has made statistically significant change before and after the introduction of euro in all of the cases when we take into account the crises to conduct empirical analyses on effects of the introduction of euro on their contributions to utility. The contribution of the Japanese yen to utility as well as that of the Swiss franc decreased in contrast with the increase in the contribution of the euro to utility after the introduction of the euro.

Regarding effects on the contribution of the Japanese yen to utility, we obtained that the US housing bubble burst, The BNP Paribas shock, the Lehman Brothers bankruptcy, and the Greek debt crisis significantly changed the contribution of the Japanese yen to utility in 5 of all 6 cases. Especially when we use real interest rates and expected inflation instead of nominal interest rates, the contribution of the Japanese yen to utility significantly decreased after the US housing bubble burst, the BNP Paribas shock, the Lehman Brothers bankruptcy, or the Greek debt crisis occurred. Given that it significantly decreased after the introduction of the euro. It seems that the Japanese yen has a decreasing trend in terms of its contribution to utility over the global financial crisis and the euro zone crisis. In the cases of using real interest rate data, the contributions of the Japanese yen to utility decreased from 0.085-0.093 before the introduction of the euro to 0.037-0.046 during a period from the introduction of the euro to two crises and then 0.029-0.032 through the two crises.

The US housing bubble burst, the BNP Paribas shock, the Lehman Brothers bankruptcy, and the Greek debt crisis had no effects on the contribution of the Pound sterling to utility. On the other hand, the events had negative effects on the contribution of the Swiss franc to utility.

4. Conclusion

In this paper, we investigated contributions of the Japanese yen and the US dollar as well as other international currencies (the euro, the Pound sterling, and the Swiss franc) to utility in a theoretical background of a money-in-the-utility model. Specifically, we estimated effects of the global financial crisis and the euro zone crisis as well as the introduction of the euro on contribution of the five international currencies to utility. The introduction of the euro had mixed 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. The empirical results suggested inertia of the US dollar as a key currency as Ogawa and Muto (2016) has already pointed out. In addition, we obtained the following empirical results as new findings in this paper.

First, the contribution of the Japanese yen to utility has significantly decreased after the introduction of euro. This corresponds to the increase in contribution of the euro to utility while the contribution of the US dollar had unchanged after the introduction of the euro. The introduction of the euro has enhanced the contribution of the euro to utility by substituting it for not the US dollar but the Japanese yen. It implies that it is evidence that the US dollar has inertia as a key currency in the current international monetary system. The contribution of the Swiss franc to utility also decreased at the same time when the contribution of the Japanese yen to utility decreased after the introduction of the euro. It seems to reflect substitution relationships of the Japanese yen and the Swiss franc with the euro.

Moreover, the US housing bubble burst, the BNP Paribas shock, the Lehman Brothers bankruptcy, and the Greek debt crisis significantly decreased the contribution of the Japanese yen to utility when we use real interest rates and expected inflation instead of nominal interest rates. It seems that the Japanese yen has a declining trend in terms of its contribution to utility over time before and after the introduction of euro and then through the global financial crisis and the euro zone crisis.

We should consider why the Japanese yen has a declining trend in terms of its contribution to utility over time before and after the introduction of euro and then through the global financial crisis and the euro zone crisis. One of the backgrounds might be related with decreasing Japanese share of GDP and international trade in the global economy while the Japanese economy has experienced "lost two decade". We should make an empirical analysis regarding a question what factors decline contribution of the Japanese yen to utility or the Japanese yen as an international currency. The question is to be solved in our future study.

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Table 1: Contribution of the USD 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	0.426	0.476	0.387	0.000	rejected
(13a) 6-month nominal interest rate	0.433	0.479	0.397	0.001	rejected
(13b) 1.5% real interest rate	0.544	0.574	0.521	0.000	rejected
(13b) 2.0% real interest rate	0.539	0.567	0.518	0.000	rejected
(13b) 2.5% real interest rate	0.537	0.566	0.516	0.000	rejected
(13b) 3.0% real interest rate	0.534	0.564	0.512	0.000	rejected

*whole:1986Q1-2016Q2,(a):1986Q1-1998Q4,(b):1999Q1-2016Q2

Table2: Contribution of the EUR 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%)
(14a) 3-month nominal interest rate	0.291	0.229	0.338	0.000	rejected
(14a) 6-month nominal interest rate	0.281	0.227	0.322	0.000	rejected
(14b) 1.5% real interest rate	0.272	0.217	0.314	0.000	rejected
(14b) 2.0% real interest rate	0.273	0.216	0.315	0.000	rejected
(14b) 2.5% real interest rate	0.272	0.215	0.314	0.000	rejected
(14b) 3.0% real interest rate	0.271	0.214	0.314	0.000	rejected

*whole:1986Q1-2016Q2,(a):1986Q1-1998Q4,(b):1999Q1-2016Q2

Table3: Contribution of the JPY 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%)
(15a) 3-month nominal interest rate	0.030	0.060	0.009	0.000	rejected
(15a) 6-month nominal interest rate	0.031	0.059	0.009	0.000	rejected
(15b) 1.5% real interest rate	0.056	0.085	0.034	0.000	rejected
(15b) 2.0% real interest rate	0.058	0.089	0.035	0.000	rejected
(15b) 2.5% real interest rate	0.060	0.091	0.036	0.000	rejected
(15b) 3.0% real interest rate	0.061	0.093	0.037	0.000	rejected

*whole:1986Q1-2016Q2,(a):1986Q1-1998Q4,(b):1999Q1-2016Q2

Table4: Contribution of the GBP 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%)
(16a) 3-month nominal interest rate	0.091	0.066	0.111	0.000	rejected
(16a) 6-month nominal interest rate	0.086	0.066	0.101	0.000	rejected
(16b) 1.5% real interest rate	0.058	0.047	0.066	0.000	rejected
(16b) 2.0% real interest rate	0.057	0.047	0.066	0.000	rejected
(16b) 2.5% real interest rate	0.057	0.046	0.066	0.000	rejected
(16b) 3.0% real interest rate	0.057	0.046	0.066	0.000	rejected

*whole:1986Q1-2016Q2,(a):1986Q1-1998Q4,(b):1999Q1-2016Q2

Table5: Contribution of the CHF 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%)
(17a) 3-month nominal interest rate	0.016	0.030	0.005	0.000	rejected
(17a) 6-month nominal interest rate	0.015	0.030	0.005	0.000	rejected
(17b) 1.5% real interest rate	0.024	0.035	0.015	0.000	rejected
(17b) 2.0% real interest rate	0.025	0.036	0.016	0.000	rejected
(17b) 2.5% real interest rate	0.025	0.036	0.016	0.000	rejected
(17b) 3.0% real interest rate	0.025	0.037	0.017	0.000	rejected

*whole:1986Q1-2016Q2,(a):1986Q1-1998Q4,(b):1999Q1-2016Q2

Table 6: Contribution of the USD 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	0.426	0.476	0.430	0.354	0.126	not rejected	0.040	not rejected
(13a) 6-month nominal interest rate	0.433	0.479	0.434	0.370	0.128	not rejected	0.063	not rejected
(13b) 1.5% real interest rate	0.544	0.574	0.552	0.498	0.053	not rejected	0.000	rejected
(13b) 2.0% real interest rate	0.539	0.567	0.545	0.498	0.024	not rejected	0.000	rejected
(13b) 2.5% real interest rate	0.537	0.566	0.541	0.497	0.008	rejected	0.000	rejected
(13b) 3.0% real interest rate	0.534	0.564	0.538	0.493	0.003	rejected	0.000	rejected

*whole:1986Q1-2016Q2,(a):1986Q1-1998Q4,(b):1999Q1-2006Q1,(c):2006Q2-2016Q2

Table 7: Contribution of the EUR 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%)
(14a) 3-month nominal interest rate	0.291	0.229	0.311	0.357	0.001	rejected	0.231	not rejected
(14a) 6-month nominal interest rate	0.281	0.227	0.307	0.332	0.001	rejected	0.461	not rejected
(14b) 1.5% real interest rate	0.272	0.217	0.293	0.330	0.000	rejected	0.002	rejected
(14b) 2.0% real interest rate	0.273	0.216	0.292	0.332	0.000	rejected	0.000	rejected
(14b) 2.5% real interest rate	0.272	0.215	0.292	0.330	0.000	rejected	0.000	rejected
(14b) 3.0% real interest rate	0.271	0.214	0.292	0.330	0.000	rejected	0.000	rejected

*whole:1986Q1-2016Q2,(a):1986Q1-1998Q4,(b):1999Q1-2006Q1,(c):2006Q2-2016Q2

Table 8: Contribution of the JPY 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%)
(15a) 3-month nominal interest rate	0.030	0.060	0.002	0.013	0.000	rejected	0.000	rejected
(15a) 6-month nominal interest rate	0.031	0.059	0.002	0.014	0.000	rejected	0.000	rejected
(15b) 1.5% real interest rate	0.056	0.085	0.039	0.031	0.000	rejected	0.036	not rejected
(15b) 2.0% real interest rate	0.058	0.089	0.042	0.030	0.000	rejected	0.000	rejected
(15b) 2.5% real interest rate	0.060	0.091	0.045	0.031	0.000	rejected	0.000	rejected
(15b) 3.0% real interest rate	0.061	0.093	0.046	0.031	0.000	rejected	0.000	rejected

*whole:1986Q1-2016Q2,(a):1986Q1-1998Q4,(b):1999Q1-2006Q1,(c):2006Q2-2016Q2

Table 9: Contribution of the GBP 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%)
(16a) 3-month nominal interest rate	0.091	0.066	0.111	0.111	0.000	rejected	0.996	not rejected
(16a) 6-month nominal interest rate	0.086	0.066	0.106	0.099	0.000	rejected	0.399	not rejected
(16b) 1.5% real interest rate	0.058	0.047	0.059	0.070	0.003	rejected	0.012	not rejected
(16b) 2.0% real interest rate	0.057	0.047	0.061	0.069	0.000	rejected	0.021	not rejected
(16b) 2.5% real interest rate	0.057	0.046	0.062	0.068	0.000	rejected	0.039	not rejected
(16b) 3.0% real interest rate	0.057	0.046	0.063	0.068	0.000	rejected	0.067	not rejected

*whole:1986Q1-2016Q2,(a):1986Q1-1998Q4,(b):1999Q1-2006Q1,(c):2006Q2-2016Q2

Table 10: Contribution of the CHF 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%)
(17a) 3-month nominal interest rate	0.016	0.030	0.009	0.001	0.000	rejected	0.001	rejected
(17a) 6-month nominal interest rate	0.015	0.030	0.010	0.001	0.000	rejected	0.000	rejected
(17b) 1.5% real interest rate	0.024	0.035	0.018	0.013	0.000	rejected	0.001	rejected
(17b) 2.0% real interest rate	0.025	0.036	0.019	0.014	0.000	rejected	0.000	rejected
(17b) 2.5% real interest rate	0.025	0.036	0.019	0.014	0.000	rejected	0.000	rejected
(17b) 3.0% real interest rate	0.025	0.037	0.020	0.014	0.000	rejected	0.000	rejected

*whole:1986Q1-2016Q2,(a):1986Q1-1998Q4,(b):1999Q1-2006Q1,(c):2006Q2-2016Q2

Table 11: Contribution of the USD 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	0.426	0.476	0.436	0.336	0.141	not rejected	0.007	rejected
(13a) 6-month nominal interest rate	0.433	0.479	0.438	0.356	0.127	not rejected	0.016	not rejected
(13b) 1.5% real interest rate	0.544	0.574	0.549	0.494	0.028	not rejected	0.000	rejected
(13b) 2.0% real interest rate	0.539	0.567	0.543	0.495	0.011	not rejected	0.000	rejected
(13b) 2.5% real interest rate	0.537	0.566	0.538	0.494	0.003	rejected	0.000	rejected
(13b) 3.0% real interest rate	0.534	0.564	0.530	0.494	0.001	rejected	0.000	rejected

*whole:1986Q1-2016Q2,(a):1986Q1-1998Q4,(b):1999Q1-2007Q2,(c):2007Q3-2016Q2

Table 12: Contribution of the EUR 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%)
(14a) 3-month nominal interest rate	0.291	0.229	0.302	0.373	0.001	rejected	0.085	not rejected
(14a) 6-month nominal interest rate	0.281	0.227	0.299	0.343	0.001	rejected	0.235	not rejected
(14b) 1.5% real interest rate	0.272	0.217	0.296	0.331	0.000	rejected	0.006	rejected
(14b) 2.0% real interest rate	0.273	0.216	0.302	0.329	0.000	rejected	0.018	not rejected
(14b) 2.5% real interest rate	0.272	0.215	0.300	0.328	0.000	rejected	0.004	rejected
(14b) 3.0% real interest rate	0.271	0.214	0.299	0.328	0.000	rejected	0.001	rejected

*whole:1986Q1-2016Q2,(a):1986Q1-1998Q4,(b):1999Q1-2007Q2,(c):2007Q3-2016Q2

Table 13: Contribution of the JPY 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%)
(15a) 3-month nominal interest rate	0.030	0.060	0.002	0.015	0.000	rejected	0.000	rejected
(15a) 6-month nominal interest rate	0.031	0.059	0.003	0.016	0.000	rejected	0.000	rejected
(15b) 1.5% real interest rate	0.056	0.085	0.037	0.032	0.000	rejected	0.174	not rejected
(15b) 2.0% real interest rate	0.058	0.089	0.040	0.031	0.000	rejected	0.002	rejected
(15b) 2.5% real interest rate	0.060	0.091	0.042	0.031	0.000	rejected	0.000	rejected
(15b) 3.0% real interest rate	0.061	0.093	0.043	0.031	0.000	rejected	0.000	rejected

*whole:1986Q1-2016Q2,(a):1986Q1-1998Q4,(b):1999Q1-2007Q2,(c):2007Q3-2016Q2

Table 14: Contribution of the GBP 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%)
(16a) 3-month nominal interest rate	0.091	0.066	0.107	0.113	0.000	rejected	0.472	not rejected
(16a) 6-month nominal interest rate	0.086	0.066	0.103	0.100	0.000	rejected	0.621	not rejected
(16b) 1.5% real interest rate	0.058	0.047	0.061	0.070	0.000	rejected	0.029	not rejected
(16b) 2.0% real interest rate	0.057	0.047	0.062	0.069	0.000	rejected	0.082	not rejected
(16b) 2.5% real interest rate	0.057	0.046	0.063	0.068	0.000	rejected	0.190	not rejected
(16b) 3.0% real interest rate	0.057	0.046	0.064	0.067	0.000	rejected	0.353	not rejected

*whole:1986Q1-2016Q2,(a):1986Q1-1998Q4,(b):1999Q1-2007Q2,(c):2007Q3-2016Q2

Table 15: Contribution of the CHF 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%)
(17a) 3-month nominal interest rate	0.016	0.030	0.009	0.000	0.000	rejected	0.003	rejected
(17a) 6-month nominal interest rate	0.015	0.030	0.009	0.000	0.000	rejected	0.000	rejected
(17b) 1.5% real interest rate	0.024	0.035	0.018	0.012	0.000	rejected	0.000	rejected
(17b) 2.0% real interest rate	0.025	0.036	0.019	0.014	0.000	rejected	0.001	rejected
(17b) 2.5% real interest rate	0.025	0.036	0.019	0.014	0.000	rejected	0.000	rejected
(17b) 3.0% real interest rate	0.025	0.037	0.019	0.014	0.000	rejected	0.000	rejected

*whole:1986Q1-2016Q2,(a):1986Q1-1998Q4,(b):1999Q1-2007Q2,(c):2007Q3-2016Q2

Table 16: Contribution of the USD 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	0.426	0.476	0.424	0.337	0.050	not rejected	0.028	not rejected
(13a) 6-month nominal interest rate	0.433	0.479	0.426	0.360	0.041	not rejected	0.066	not rejected
(13b) 1.5% real interest rate	0.544	0.574	0.543	0.494	0.007	rejected	0.000	rejected
(13b) 2.0% real interest rate	0.539	0.567	0.537	0.496	0.002	rejected	0.000	rejected
(13b) 2.5% real interest rate	0.537	0.566	0.533	0.496	0.000	rejected	0.000	rejected
(13b) 3.0% real interest rate	0.534	0.564	0.525	0.495	0.000	rejected	0.001	rejected

*whole:1986Q1-2016Q2,(a):1986Q1-1998Q4,(b):1999Q1-2008Q2,(c):2008Q3-2016Q2

Table 17: Contribution of the EUR 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%)
(14a) 3-month nominal interest rate	0.291	0.229	0.311	0.371	0.000	rejected	0.179	not rejected
(14a) 6-month nominal interest rate	0.281	0.227	0.308	0.338	0.000	rejected	0.465	not rejected
(14b) 1.5% real interest rate	0.272	0.217	0.300	0.330	0.000	rejected	0.025	not rejected
(14b) 2.0% real interest rate	0.273	0.216	0.305	0.328	0.000	rejected	0.050	not rejected
(14b) 2.5% real interest rate	0.272	0.215	0.304	0.327	0.000	rejected	0.018	not rejected
(14b) 3.0% real interest rate	0.271	0.214	0.303	0.327	0.000	rejected	0.008	rejected

*whole:1986Q1-2016Q2,(a):1986Q1-1998Q4,(b):1999Q1-2008Q2,(c):2008Q3-2016Q2

Table 18: Contribution of the JPY 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%)
(15a) 3-month nominal interest rate	0.030	0.060	0.003	0.015	0.000	rejected	0.000	rejected
(15a) 6-month nominal interest rate	0.031	0.059	0.003	0.016	0.000	rejected	0.000	rejected
(15b) 1.5% real interest rate	0.056	0.085	0.036	0.032	0.000	rejected	0.349	not rejected
(15b) 2.0% real interest rate	0.058	0.089	0.039	0.031	0.000	rejected	0.006	rejected
(15b) 2.5% real interest rate	0.060	0.091	0.041	0.031	0.000	rejected	0.001	rejected
(15b) 3.0% real interest rate	0.061	0.093	0.042	0.032	0.000	rejected	0.000	rejected

*whole:1986Q1-2016Q2,(a):1986Q1-1998Q4,(b):1999Q1-2008Q2,(c):2008Q3-2016Q2

Table 19: Contribution of the GBP 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%)
(16a) 3-month nominal interest rate	0.091	0.066	0.110	0.111	0.000	rejected	0.818	not rejected
(16a) 6-month nominal interest rate	0.086	0.066	0.106	0.096	0.000	rejected	0.152	not rejected
(16b) 1.5% real interest rate	0.058	0.047	0.063	0.069	0.000	rejected	0.190	not rejected
(16b) 2.0% real interest rate	0.057	0.047	0.065	0.067	0.000	rejected	0.539	not rejected
(16b) 2.5% real interest rate	0.057	0.046	0.066	0.066	0.000	rejected	0.979	not rejected
(16b) 3.0% real interest rate	0.057	0.046	0.066	0.065	0.000	rejected	0.568	not rejected

*whole:1986Q1-2016Q2,(a):1986Q1-1998Q4,(b):1999Q1-2008Q2,(c):2008Q3-2016Q2

Table 20: Contribution of the CHF 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%)
(17a) 3-month nominal interest rate	0.016	0.030	0.009	-0.002	0.000	rejected	0.001	rejected
(17a) 6-month nominal interest rate	0.015	0.030	0.009	-0.001	0.000	rejected	0.000	rejected
(17b) 1.5% real interest rate	0.024	0.035	0.018	0.012	0.000	rejected	0.001	rejected
(17b) 2.0% real interest rate	0.025	0.036	0.018	0.014	0.000	rejected	0.008	rejected
(17b) 2.5% real interest rate	0.025	0.036	0.018	0.014	0.000	rejected	0.001	rejected
(17b) 3.0% real interest rate	0.025	0.037	0.018	0.015	0.000	rejected	0.000	rejected

*whole:1986Q1-2016Q2,(a):1986Q1-1998Q4,(b):1999Q1-2008Q2,(c):2008Q3-2016Q2

Table 21: Contribution of the USD 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	0.426	0.476	0.406	0.352	0.007	rejected	0.223	not rejected
(13a) 6-month nominal interest rate	0.433	0.479	0.413	0.370	0.008	rejected	0.278	not rejected
(13b) 1.5% real interest rate	0.544	0.574	0.536	0.498	0.002	rejected	0.008	rejected
(13b) 2.0% real interest rate	0.539	0.567	0.531	0.498	0.000	rejected	0.003	rejected
(13b) 2.5% real interest rate	0.537	0.566	0.527	0.498	0.000	rejected	0.002	rejected
(13b) 3.0% real interest rate	0.534	0.564	0.521	0.498	0.000	rejected	0.010	not rejected

*whole:1986Q1-2016Q2,(a):1986Q1-1998Q4,(b):1999Q1-2009Q3,(c):2009Q4-2016Q2

Table 22: Contribution of the EUR 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%)
(14a) 3-month nominal interest rate	0.291	0.229	0.330	0.352	0.000	rejected	0.665	not rejected
(14a) 6-month nominal interest rate	0.281	0.227	0.321	0.322	0.000	rejected	0.983	not rejected
(14b) 1.5% real interest rate	0.272	0.217	0.308	0.324	0.000	rejected	0.204	not rejected
(14b) 2.0% real interest rate	0.273	0.216	0.310	0.323	0.000	rejected	0.243	not rejected
(14b) 2.5% real interest rate	0.272	0.215	0.309	0.323	0.000	rejected	0.126	not rejected
(14b) 3.0% real interest rate	0.271	0.214	0.308	0.323	0.000	rejected	0.073	not rejected

*whole:1986Q1-2016Q2,(a):1986Q1-1998Q4,(b):1999Q1-2009Q3,(c):2009Q4-2016Q2

Table 23: Contribution of the JPY 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%)
(15a) 3-month nominal interest rate	0.030	0.060	0.005	0.015	0.000	rejected	0.000	rejected
(15a) 6-month nominal interest rate	0.031	0.059	0.005	0.016	0.000	rejected	0.000	rejected
(15b) 1.5% real interest rate	0.056	0.085	0.038	0.029	0.000	rejected	0.010	not rejected
(15b) 2.0% real interest rate	0.058	0.089	0.039	0.029	0.000	rejected	0.000	rejected
(15b) 2.5% real interest rate	0.060	0.091	0.041	0.030	0.000	rejected	0.000	rejected
(15b) 3.0% real interest rate	0.061	0.093	0.042	0.030	0.000	rejected	0.000	rejected

*whole:1986Q1-2016Q2,(a):1986Q1-1998Q4,(b):1999Q1-2009Q3,(c):2009Q4-2016Q2

Table 24: Contribution of the GBP 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%)
(16a) 3-month nominal interest rate	0.091	0.066	0.110	0.111	0.000	rejected	0.867	not rejected
(16a) 6-month nominal interest rate	0.086	0.066	0.105	0.096	0.000	rejected	0.144	not rejected
(16b) 1.5% real interest rate	0.058	0.047	0.064	0.068	0.000	rejected	0.385	not rejected
(16b) 2.0% real interest rate	0.057	0.047	0.066	0.065	0.000	rejected	0.962	not rejected
(16b) 2.5% real interest rate	0.057	0.046	0.067	0.064	0.000	rejected	0.408	not rejected
(16b) 3.0% real interest rate	0.057	0.046	0.067	0.063	0.000	rejected	0.139	not rejected

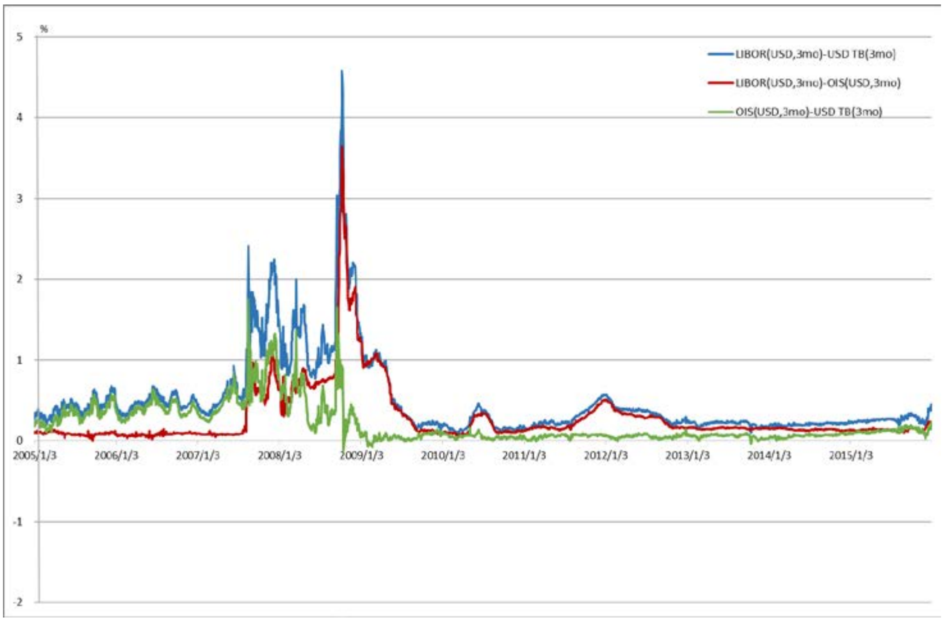
*whole:1986Q1-2016Q2,(a):1986Q1-1998Q4,(b):1999Q1-2009Q3,(c):2009Q4-2016Q2

Table 25: Contribution of the CHF 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%)
(17a) 3-month nominal interest rate	0.016	0.030	0.009	-0.004	0.000	rejected	0.001	rejected
(17a) 6-month nominal interest rate	0.015	0.030	0.009	-0.003	0.000	rejected	0.000	rejected
(17b) 1.5% real interest rate	0.024	0.035	0.017	0.013	0.000	rejected	0.015	not rejected
(17b) 2.0% real interest rate	0.025	0.036	0.018	0.014	0.000	rejected	0.001	rejected
(17b) 2.5% real interest rate	0.025	0.036	0.018	0.014	0.000	rejected	0.000	rejected
(17b) 3.0% real interest rate	0.025	0.037	0.018	0.014	0.000	rejected	0.000	rejected

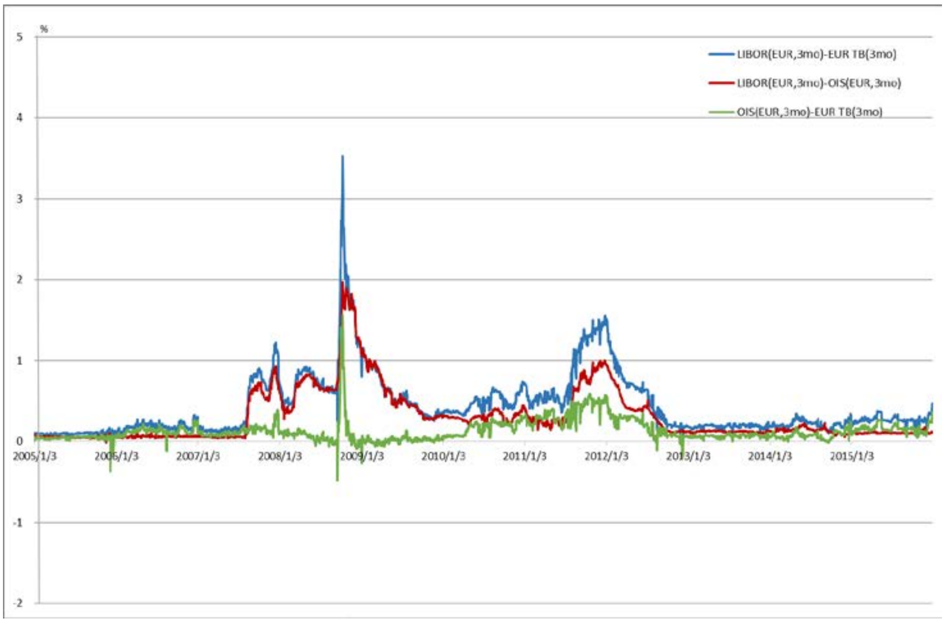
*whole:1986Q1-2016Q2,(a):1986Q1-1998Q4,(b):1999Q1-2009Q3,(c):2009Q4-2016Q2

Figure 1a: Credit risk premium and liquidity risk premium for the USD



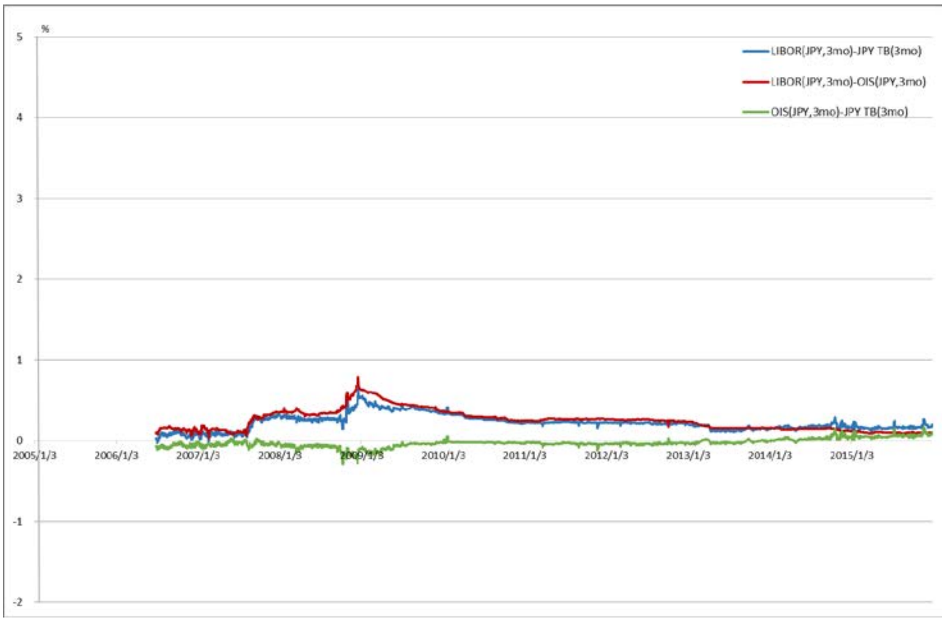
Data: Datastream, Credit risk = London Interbank Offered Rate (LIBOR) (USD, 3 months) minus Overnight Indexed Swap (OIS) rate (USD, 3 months), liquidity risk = OIS minus US Treasury Bills (TB) rate (USD, 3 months)

Figure 1b: Credit risk premium and liquidity risk premium for the EUR



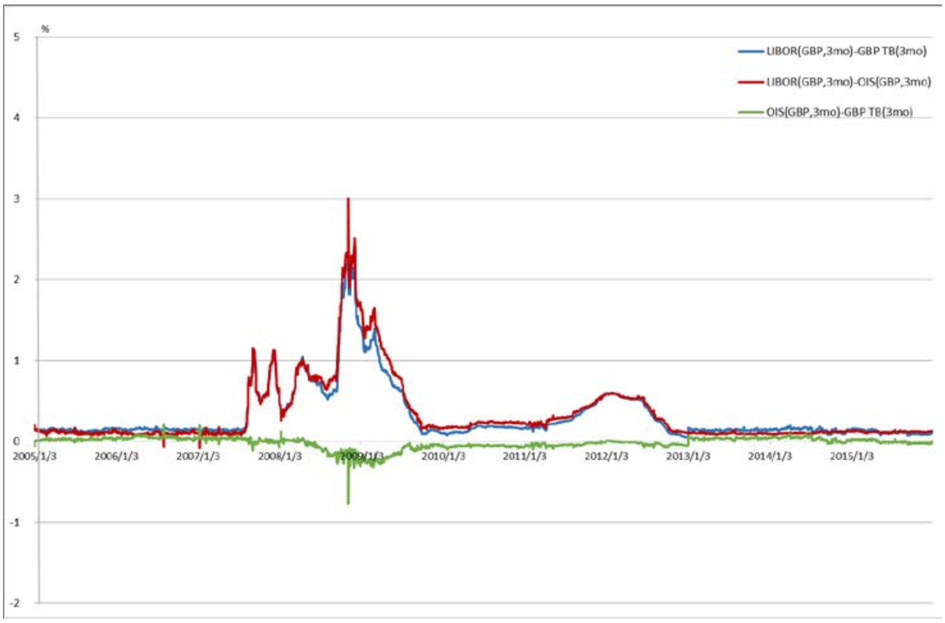
Data: Datastream, Credit risk = London Interbank Offered Rate (LIBOR) (EUR, 3 months) minus Overnight Indexed Swap (OIS) rate (EUR, 3 months), liquidity risk = OIS minus yields on German treasury discount paper (Bubills) (EUR TB rate) (euro, 3 months)

Figure 1c: Credit risk premium and liquidity risk premium for the JPY



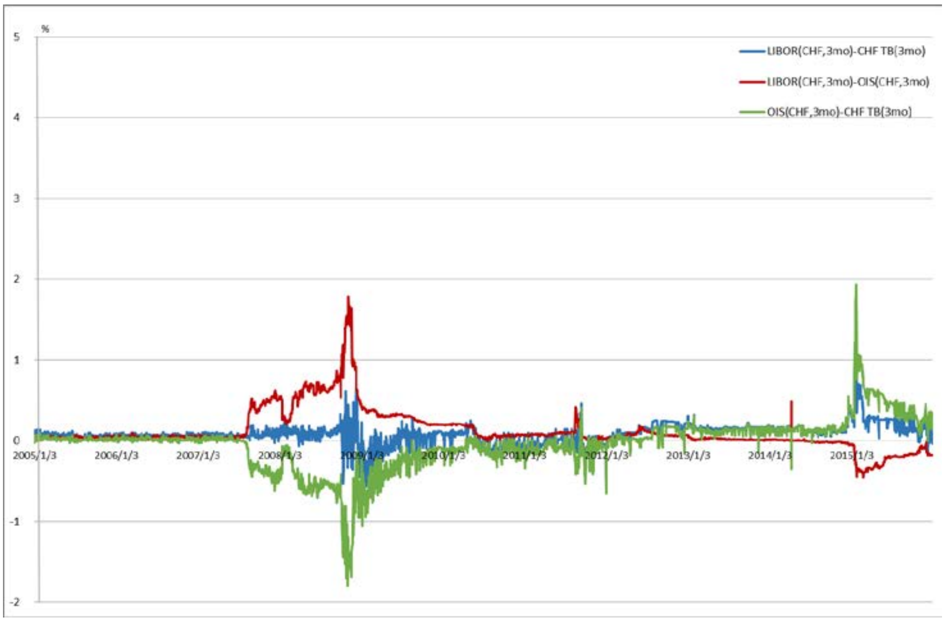
Data: Datastream, Credit risk = London Interbank Offered Rate (LIBOR) (JPY, 3 months) minus Overnight Indexed Swap (OIS) rate (JPY, 3 months), liquidity risk = OIS minus yields on Japanese Treasury Discount Bills (JPY TB rate) (JPY, 3 months)

Figure 1d: Credit risk premium and liquidity risk premium for the GBP



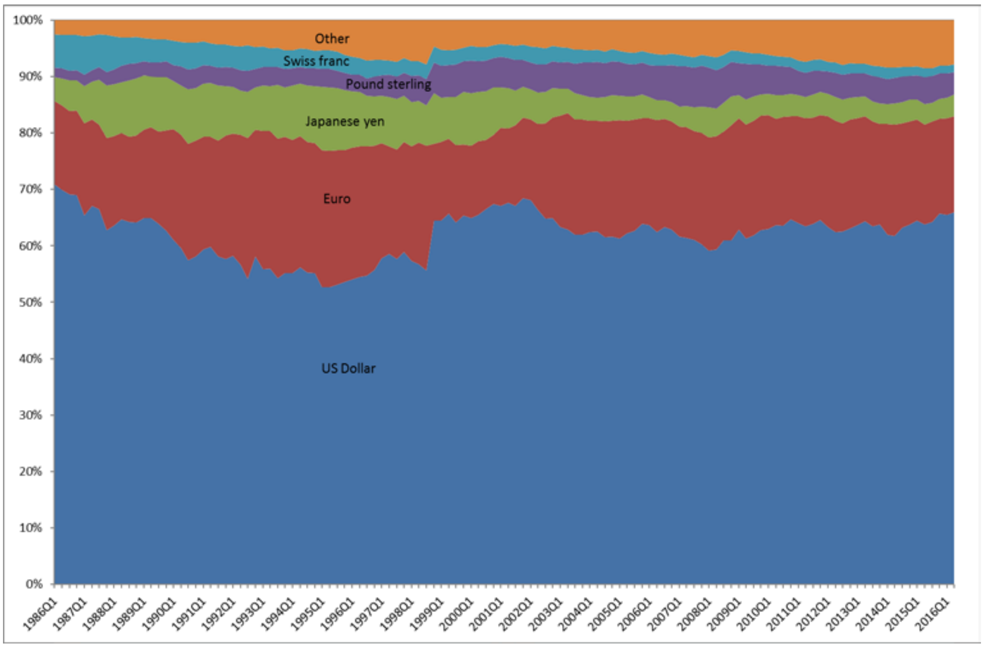
Data: Datastream, Credit risk = London Interbank Offered Rate (LIBOR) (GBP, 3 months) minus Overnight Indexed Swap (OIS) rate (GBP, 3 months), liquidity risk = OIS minus Yields on UK Government bonds (gilts) (GBP TB rate) (GBP, 3 months)

Figure 1e: Credit risk premium and liquidity risk premium for the CHF



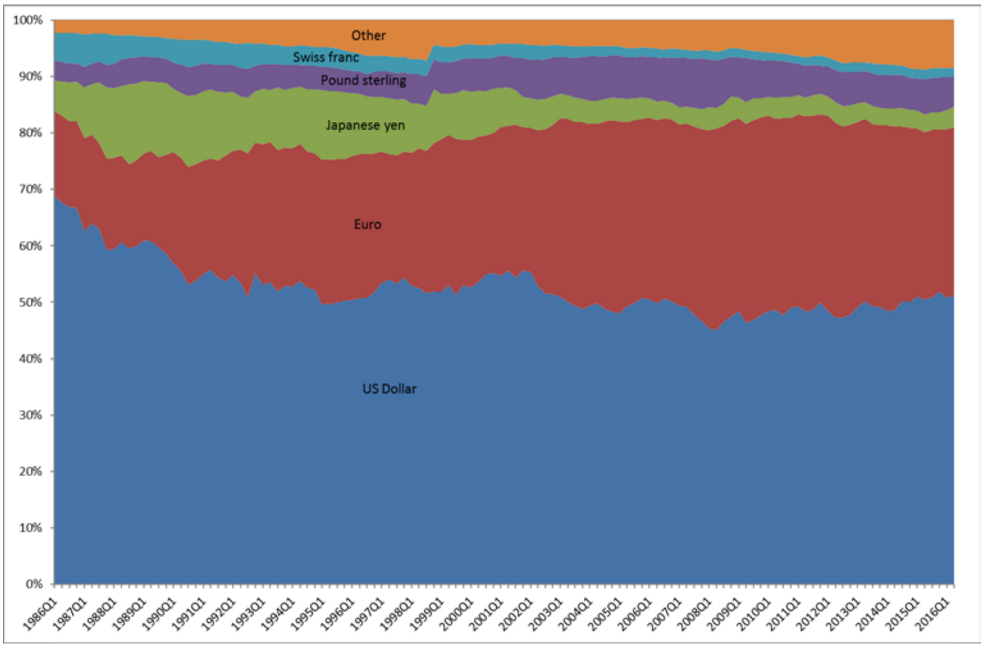
Data: Datastream, Credit risk = London Interbank Offered Rate (LIBOR) (CHF, 3 months) minus Overnight Indexed Swap (OIS) rate (CHF, 3 months), liquidity risk = OIS minus Yields on Switzerland Government bond (CHF TB rate) (CHF, 3 months)

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



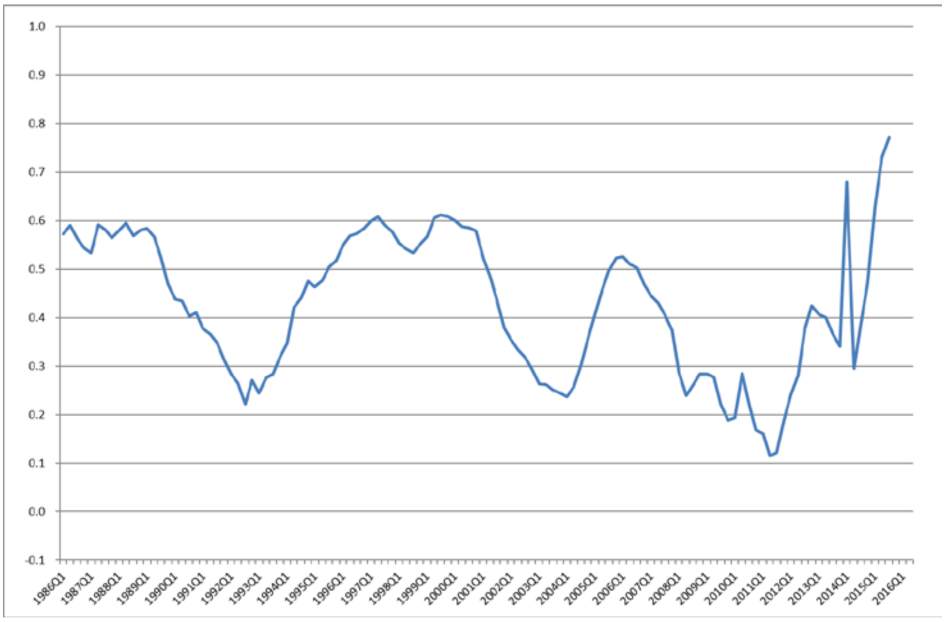
Data: BIS

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



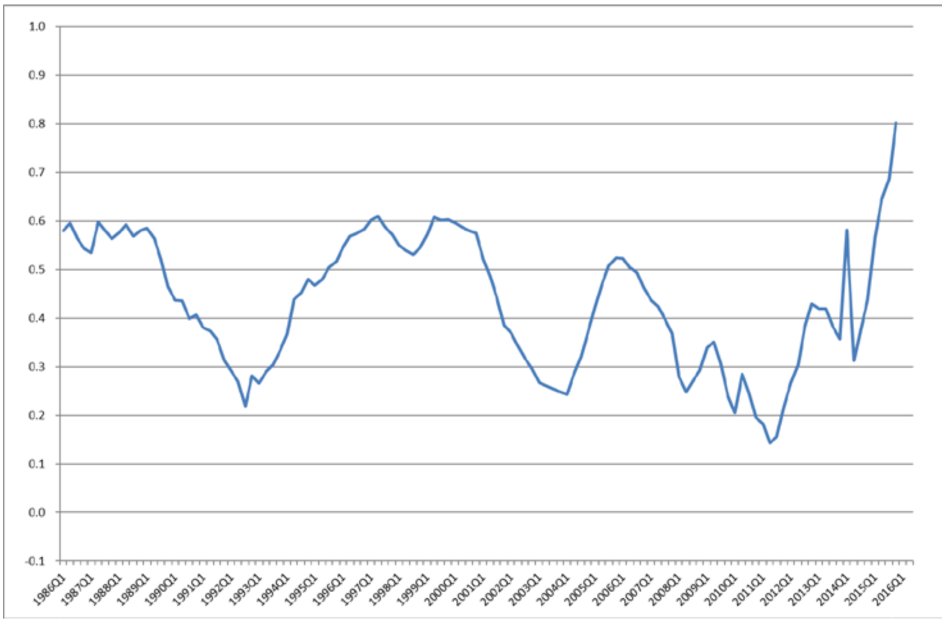
Data: BIS

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



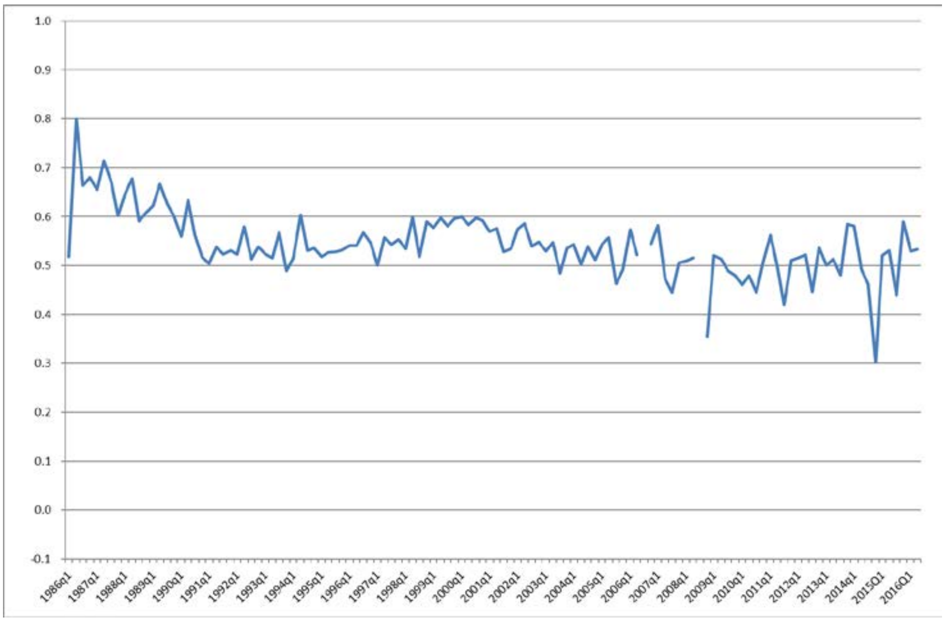
*Outliers which are beyond three times of standard deviation are excluded from our sample.

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



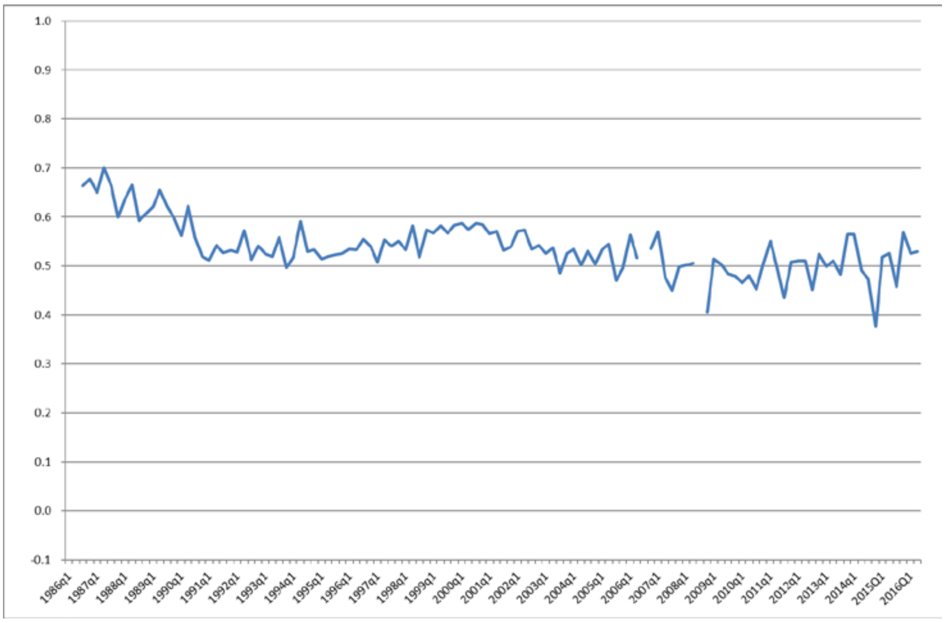
*Outliers which are beyond three times of standard deviation are excluded from our sample.

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



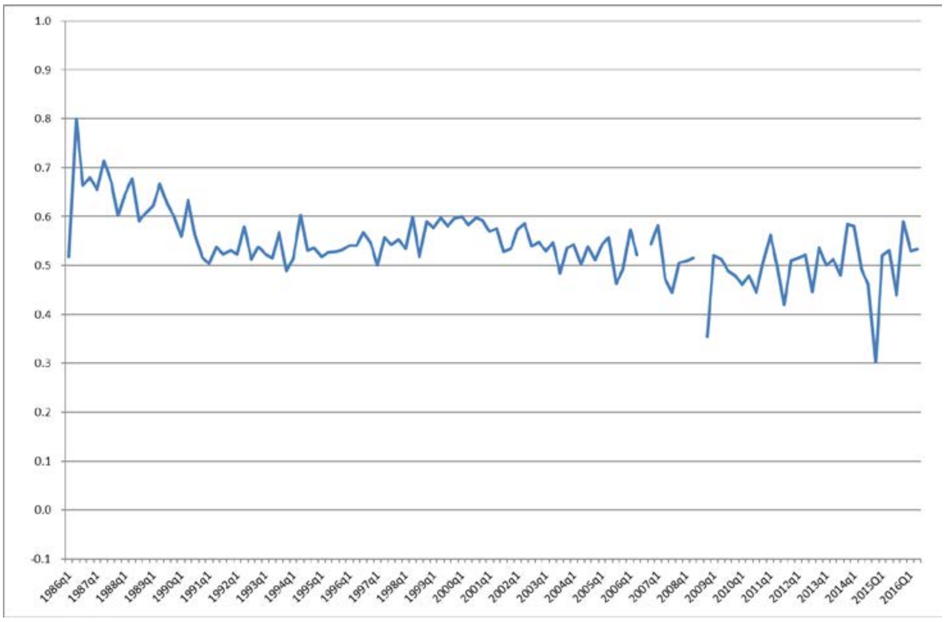
*Outliers which are beyond three times of standard deviation are excluded from our sample.

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



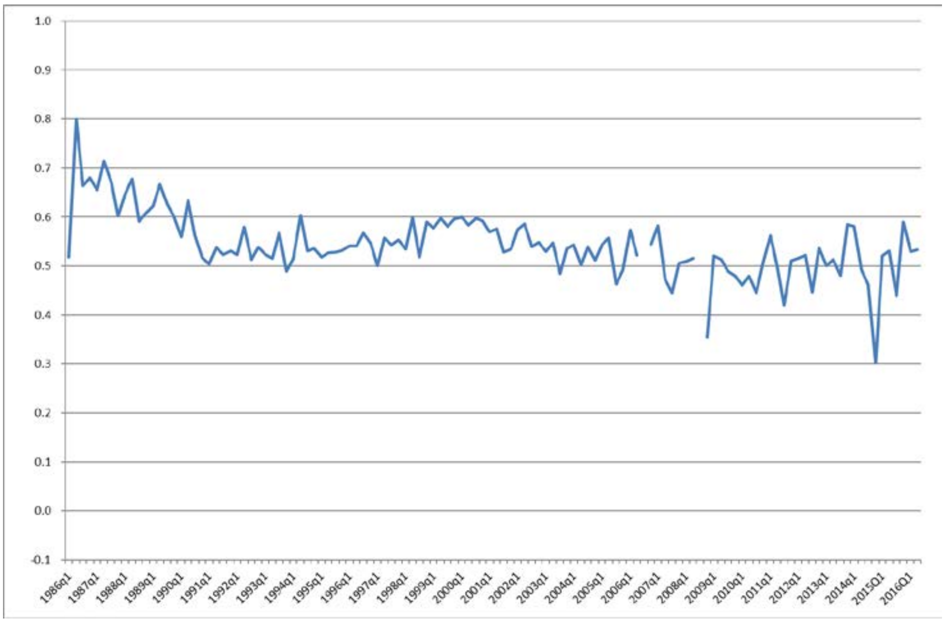
*Outliers which are beyond three times of standard deviation are excluded from our sample.

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



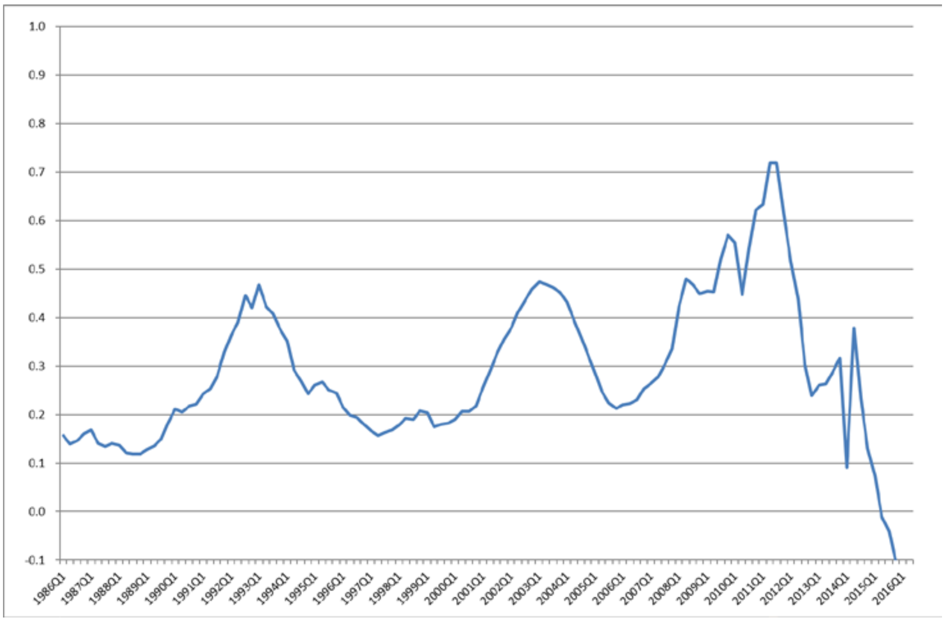
*Outliers which are beyond three times of standard deviation are excluded from our sample.

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



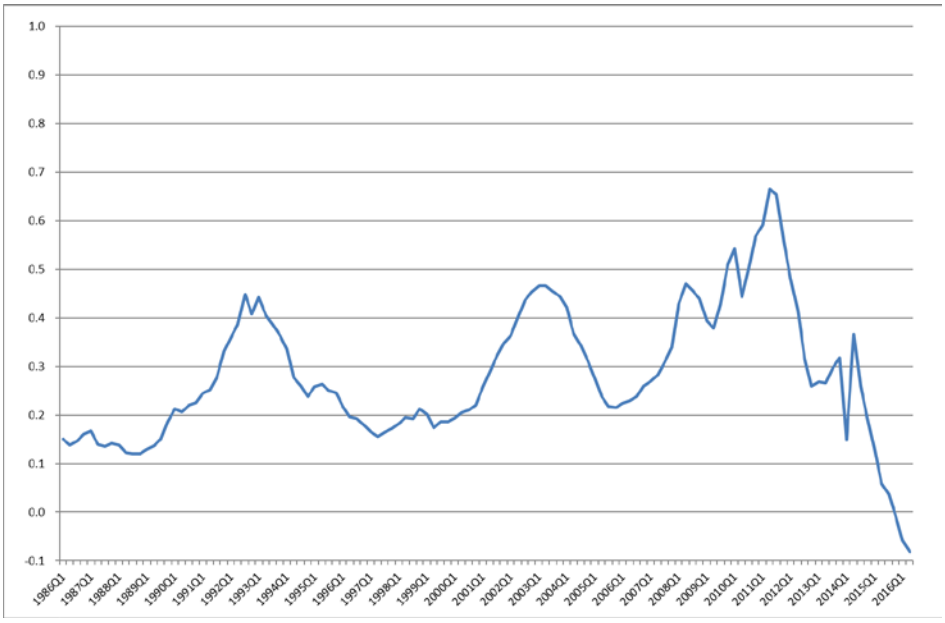
*Outliers which are beyond three times of standard deviation are excluded from our sample.

Figure 4a: Contribution of the EUR to utility in the case of using data on 3-month nominal interest rate in model (13a)



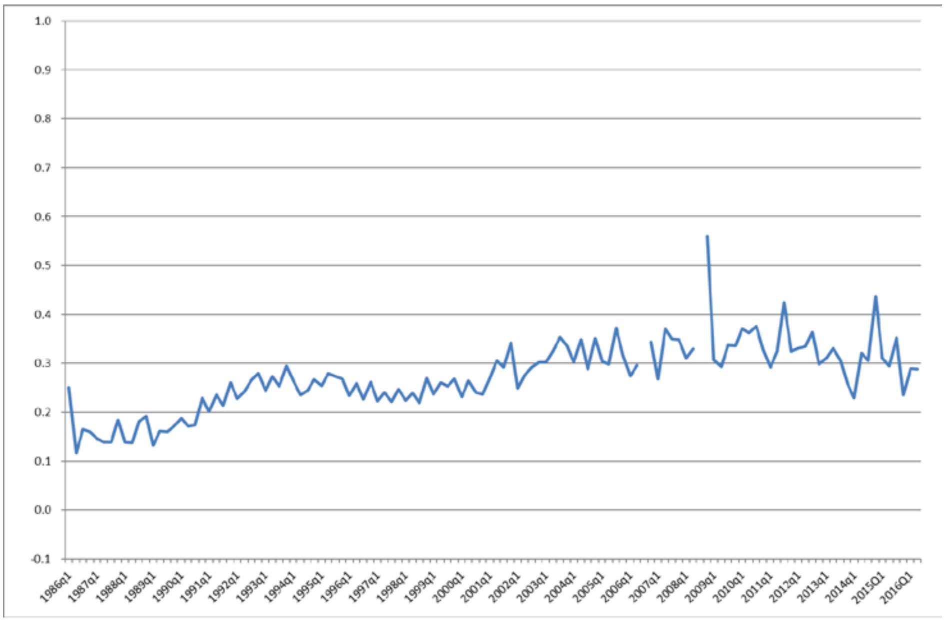
*Outliers which are beyond three times of standard deviation are excluded from our sample.

Figure 4b: Contribution of the EUR to utility in the case of using data on 6-month nominal interest rate in model (13a)



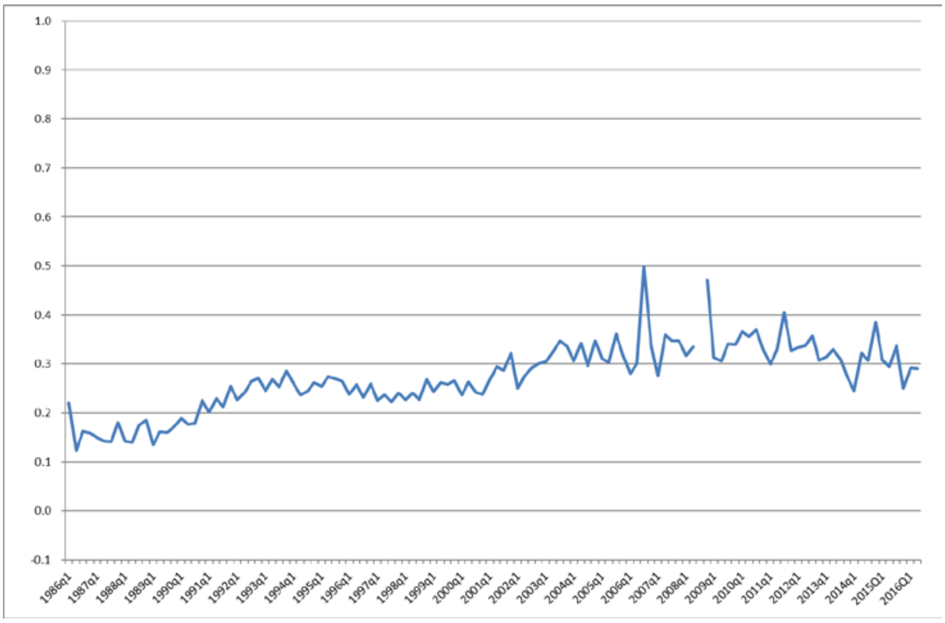
*Outliers which are beyond three times of standard deviation are excluded from our sample.

Figure 4c: Contribution of the EUR to utility in the case of setting 1.5% as a real interest rate in model (13b)



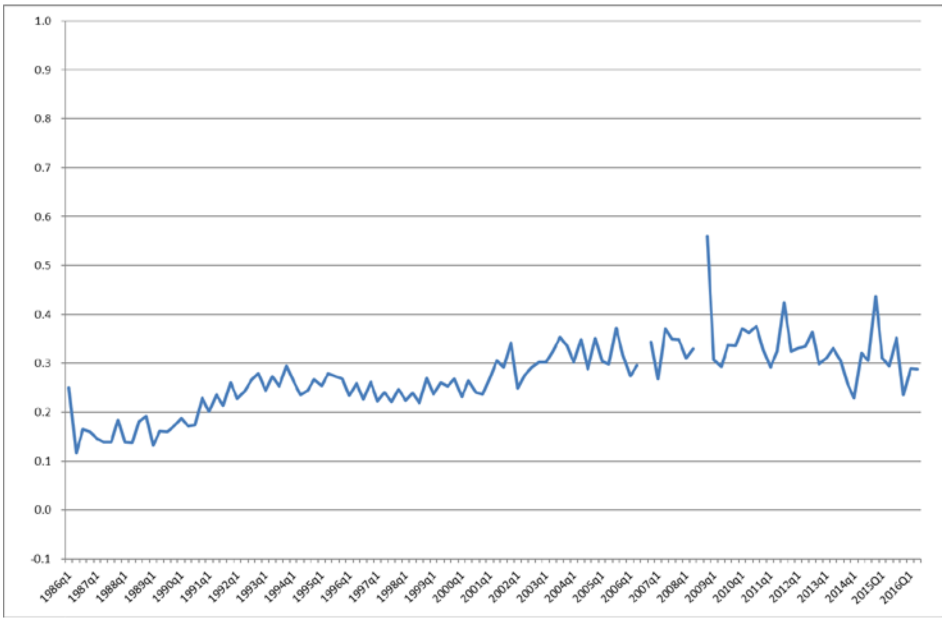
*Outliers which are beyond three times of standard deviation are excluded from our sample.

Figure 4d: Contribution of the EUR to utility in the case of setting 2.0% as a real interest rate in model (13b)



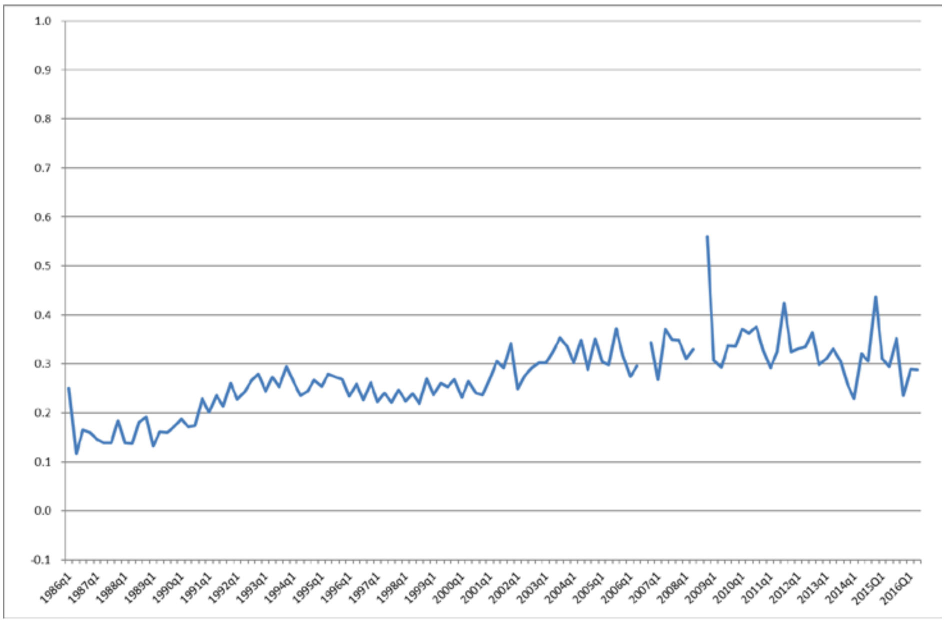
*Outliers which are beyond three times of standard deviation are excluded from our sample.

Figure 4e: Contribution of the EUR to utility in the case of setting 2.5% as a real interest rate in model (13b)



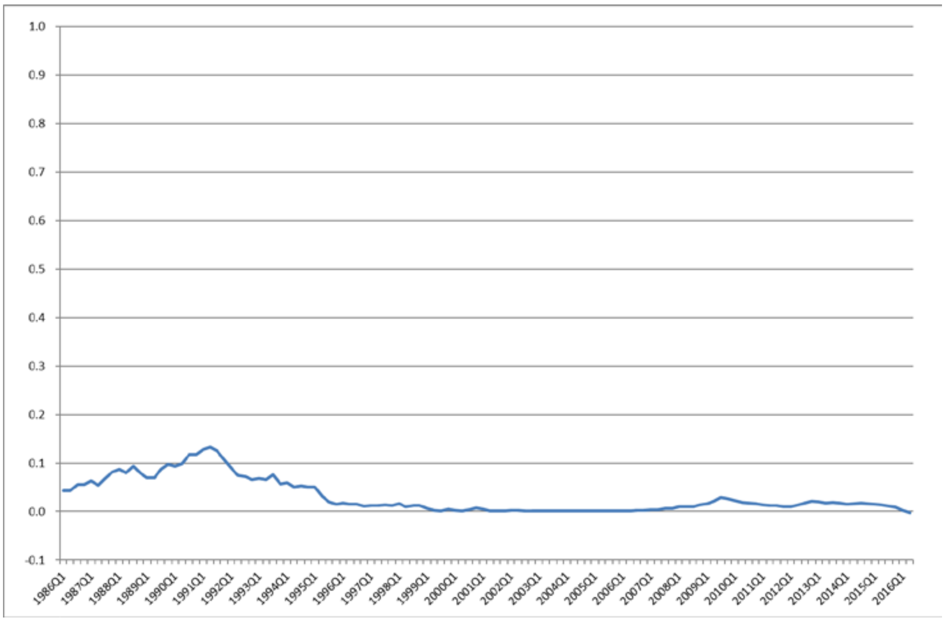
*Outliers which are beyond three times of standard deviation are excluded from our sample.

Figure 4f: Contribution of the EUR to utility in the case of setting 3.0% as a real interest rate in model (13b)



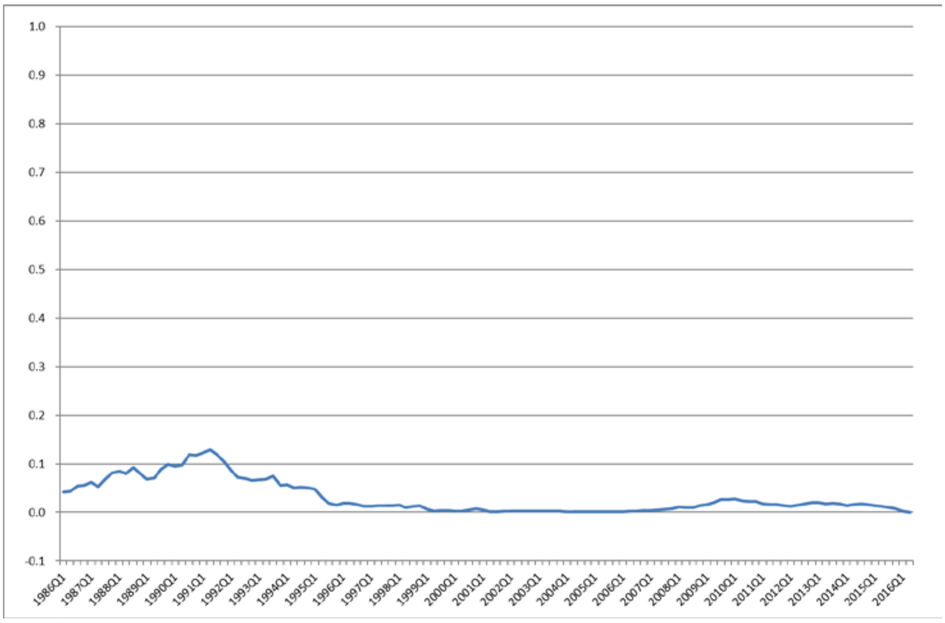
*Outliers which are beyond three times of standard deviation are excluded from our sample.

Figure 5a: Contribution of the JPY to utility in the case of using data on 3-month nominal interest rate in model (13a)



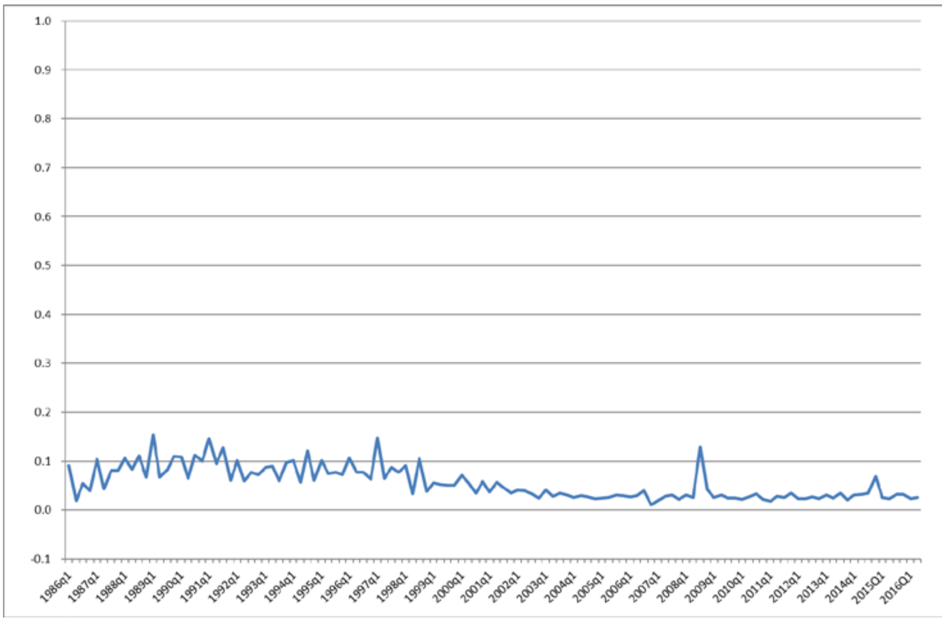
*Outliers which are beyond three times of standard deviation are excluded from our sample.

Figure 5b: Contribution of the JPY to utility in the case of using data on 6-month nominal interest rate in model (13a)



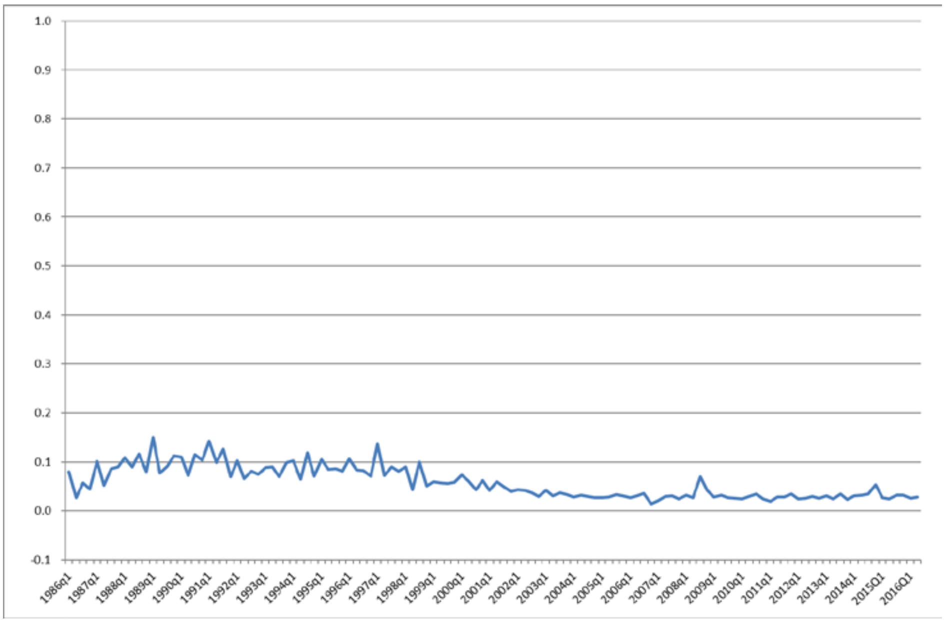
*Outliers which are beyond three times of standard deviation are excluded from our sample.

Figure 5c: Contribution of the JPY to utility in the case of setting 1.5% as a real interest rate in model (13b)



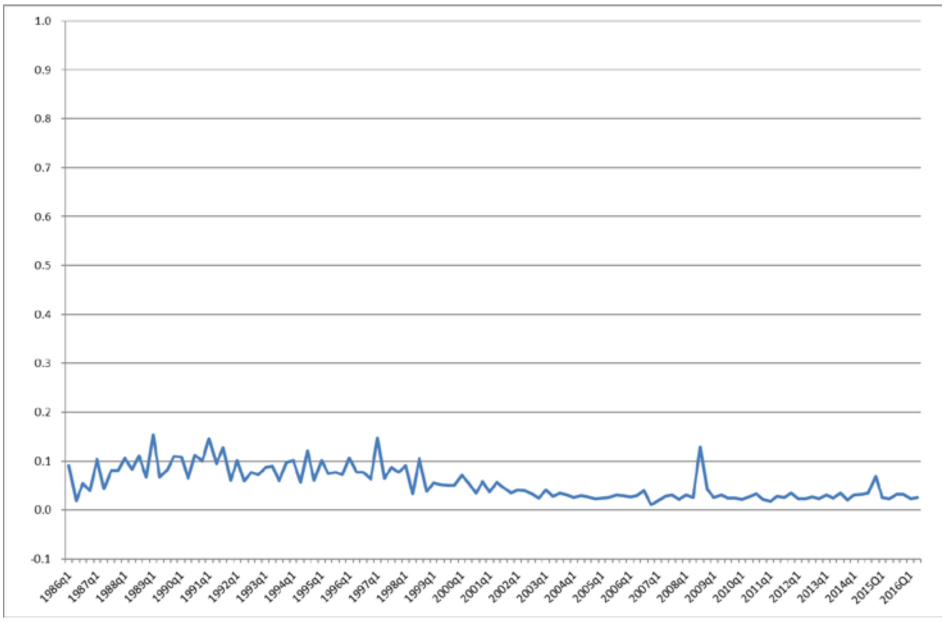
*Outliers which are beyond three times of standard deviation are excluded from our sample.

Figure 5d: Contribution of the JPY to utility in the case of setting 2.0% as a real interest rate in model (13b)



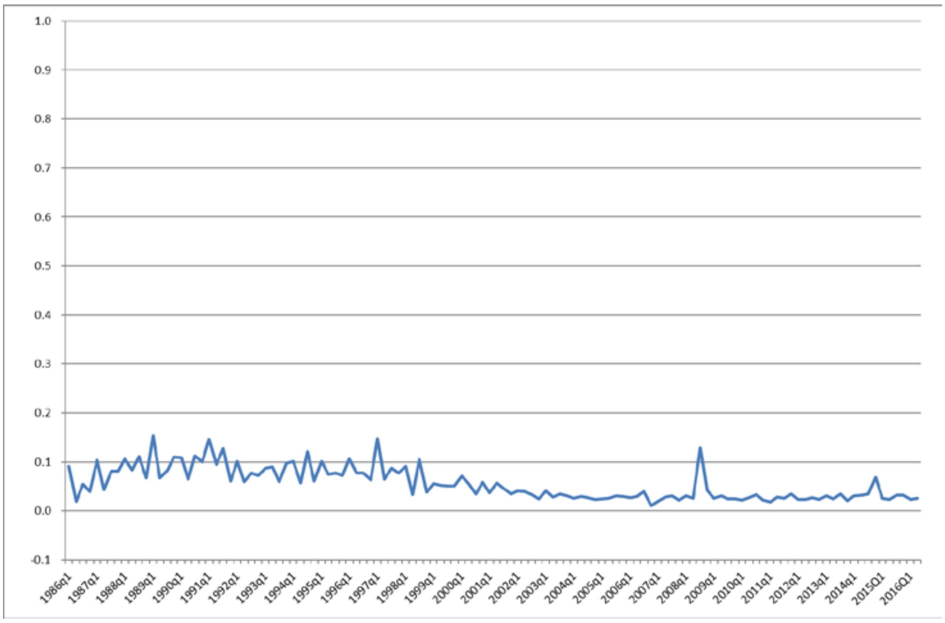
*Outliers which are beyond three times of standard deviation are excluded from our sample.

Figure 5e: Contribution of the JPY to utility in the case of setting 2.5% as a real interest rate in model (13b)



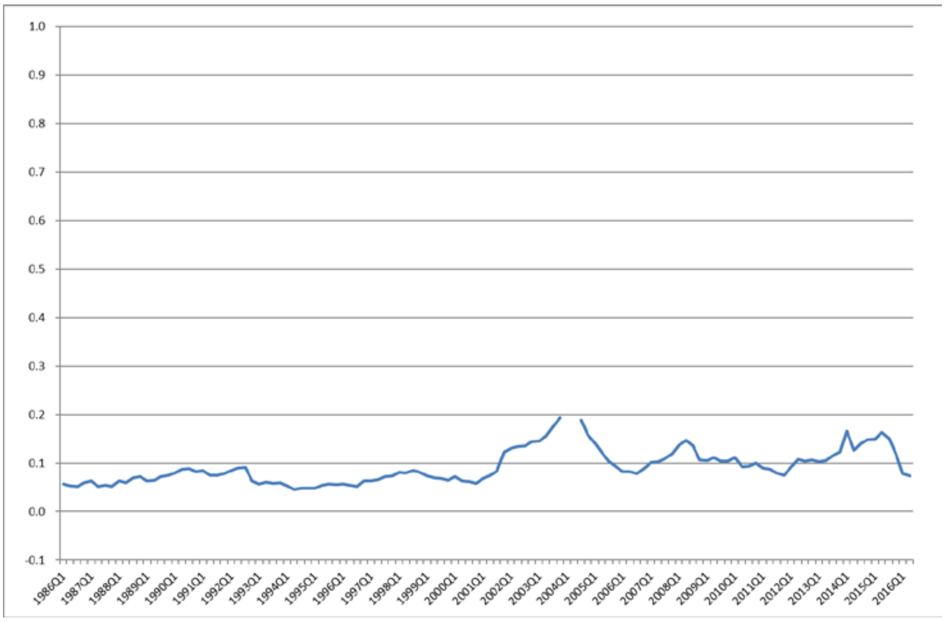
*Outliers which are beyond three times of standard deviation are excluded from our sample.

Figure 5f: Contribution of the JPY to utility in the case of setting 3.0% as a real interest rate in model (13b)



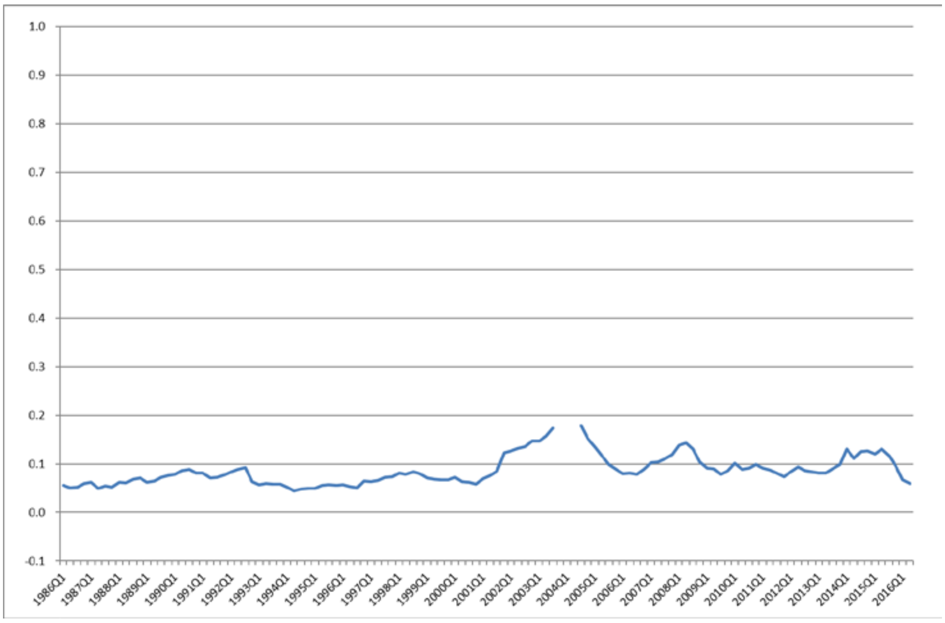
*Outliers which are beyond three times of standard deviation are excluded from our sample.

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



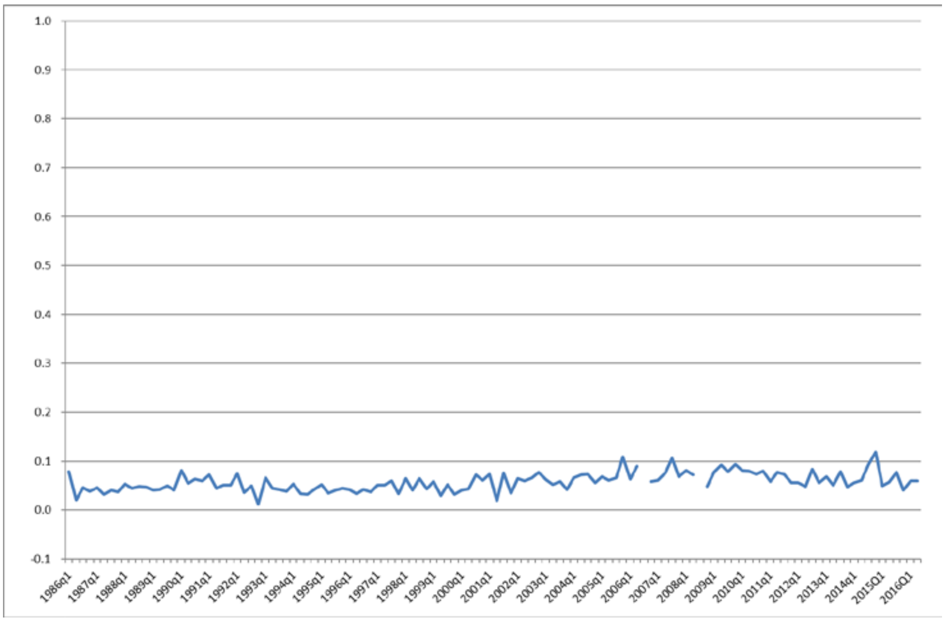
*Outliers which are beyond three times of standard deviation are excluded from our sample.

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



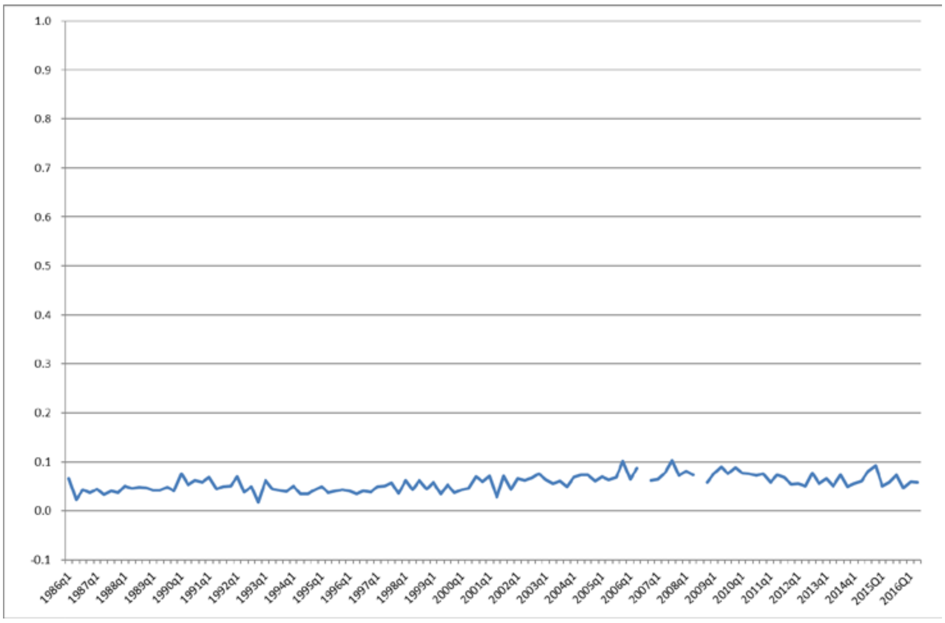
*Outliers which are beyond three times of standard deviation are excluded from our sample.

Figure 6c: Contribution of the GBP to utility in the case of setting 1.5% as a real interest rate in model (13b)



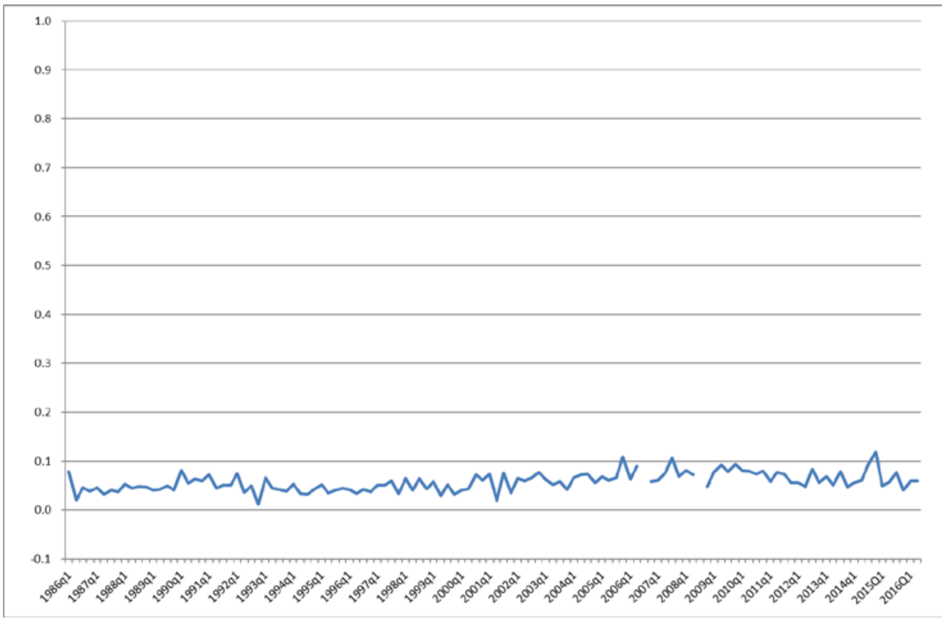
*Outliers which are beyond three times of standard deviation are excluded from our sample.

Figure 6d: Contribution of the GBP to utility in the case of setting 2.0% as a real interest rate in model (13b)



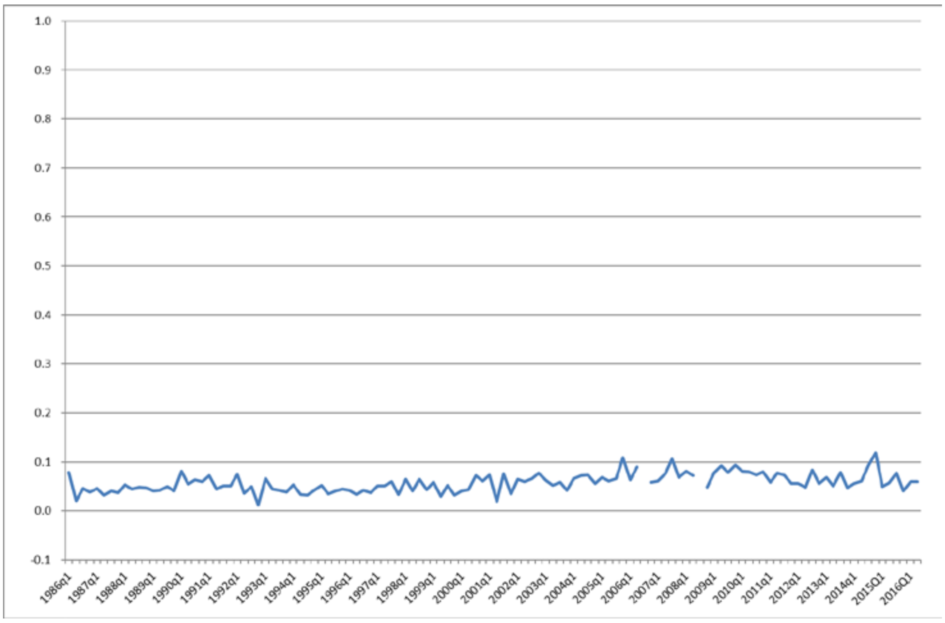
*Outliers which are beyond three times of standard deviation are excluded from our sample.

Figure 6e: Contribution of the GBP to utility in the case of setting 2.5% as a real interest rate in model (13b)



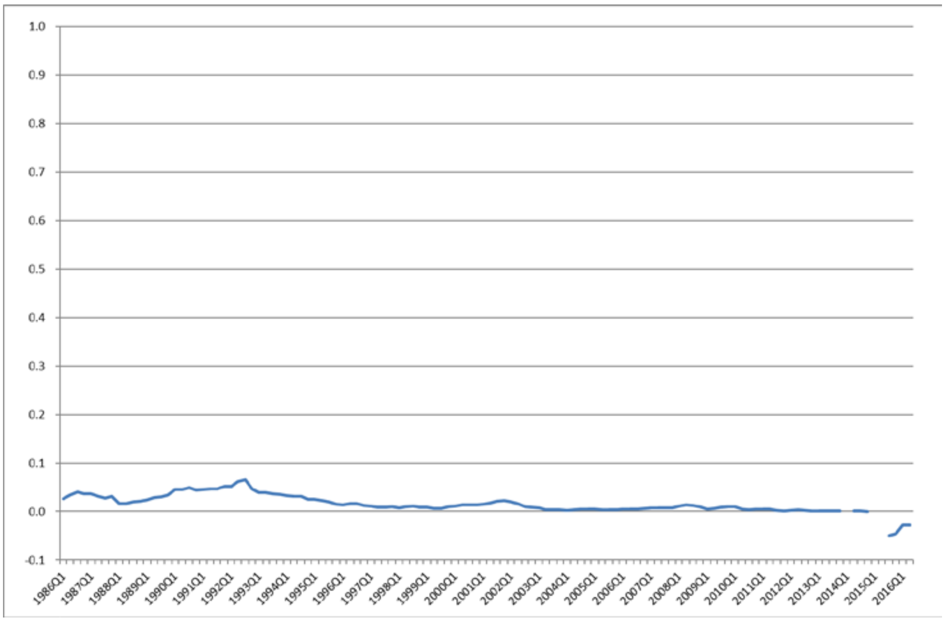
*Outliers which are beyond three times of standard deviation are excluded from our sample.

Figure 6f: Contribution of the GBP to utility in the case of setting 3.0% as a real interest rate in model (13b)



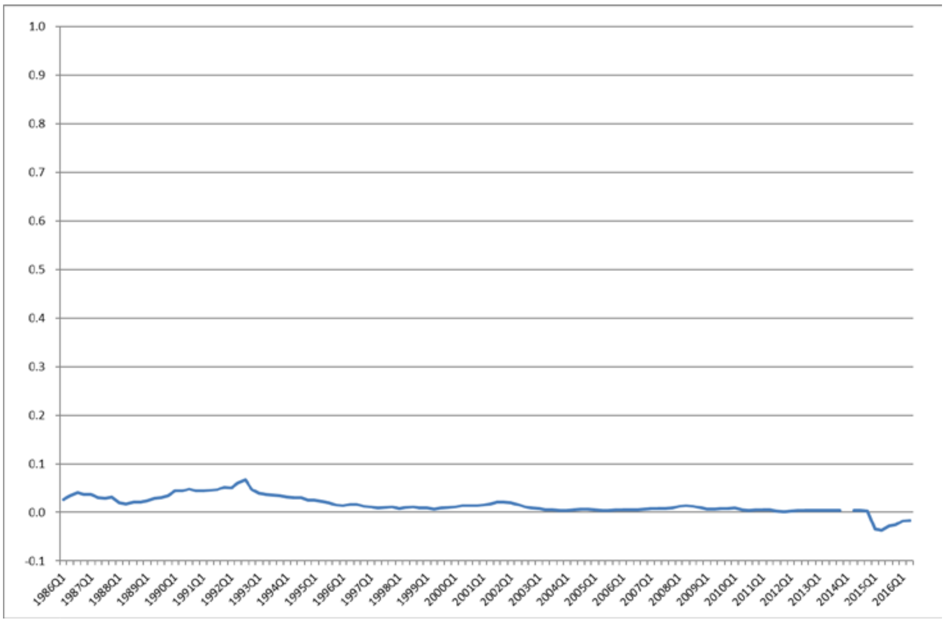
*Outliers which are beyond three times of standard deviation are excluded from our sample.

Figure 7a: Contribution of the CHF to utility in the case of using data on 3-month nominal interest rate in model (13a)



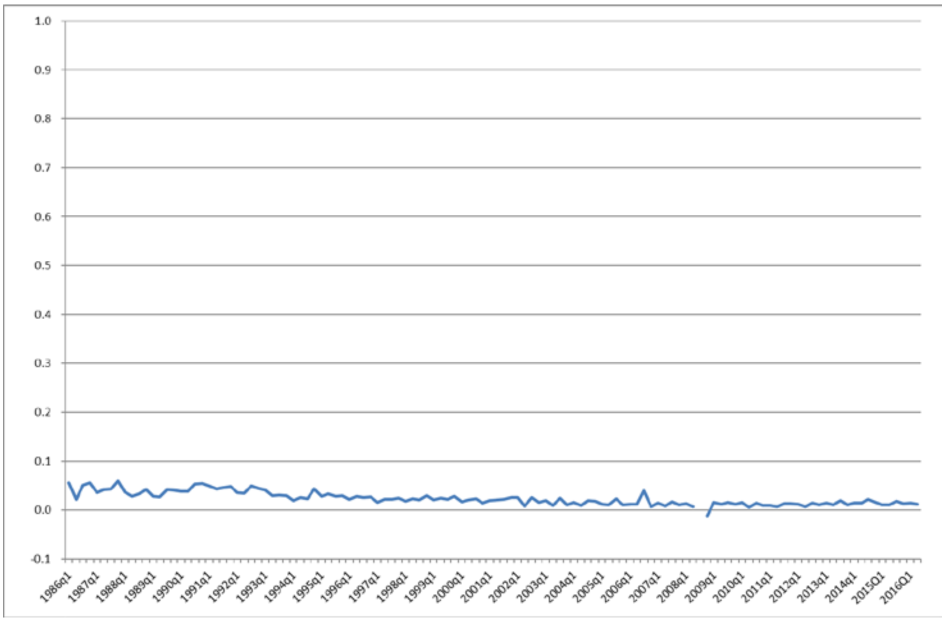
*Outliers which are beyond three times of standard deviation are excluded from our sample.

Figure 7b: Contribution of the CHF to utility in the case of using data on 6-month nominal interest rate in model (13a)



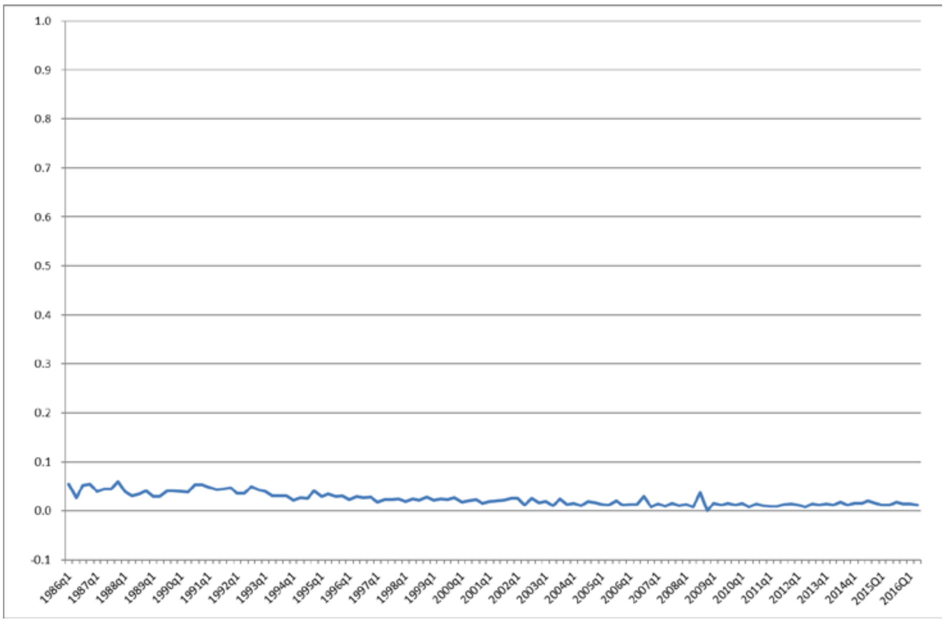
*Outliers which are beyond three times of standard deviation are excluded from our sample.

Figure 7c: Contribution of the CHF to utility in the case of setting 1.5% as a real interest rate in model (13b)



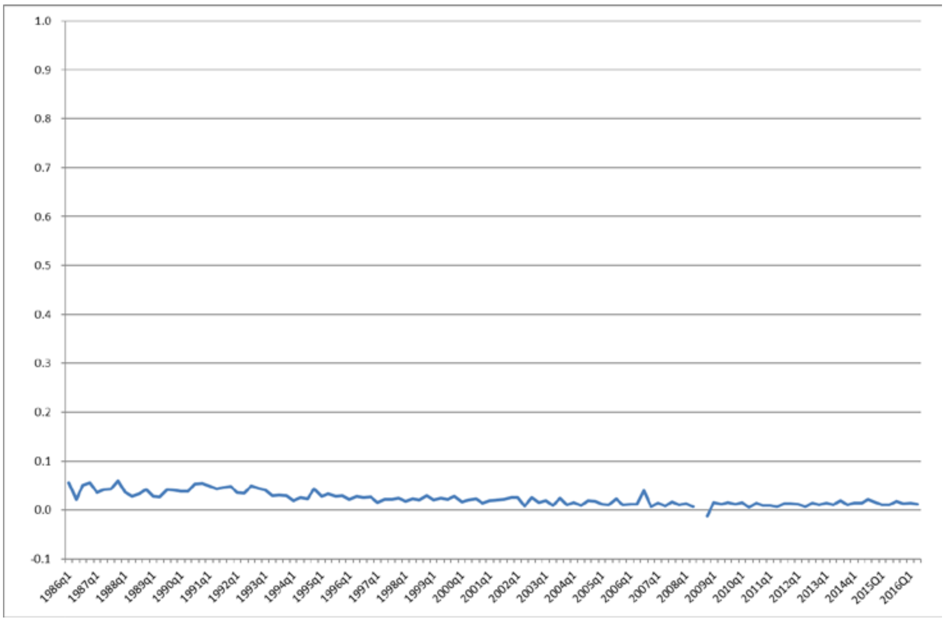
*Outliers which are beyond three times of standard deviation are excluded from our sample.

Figure 7d: Contribution of the CHF to utility in the case of setting 2.0% as a real interest rate in model (13b)



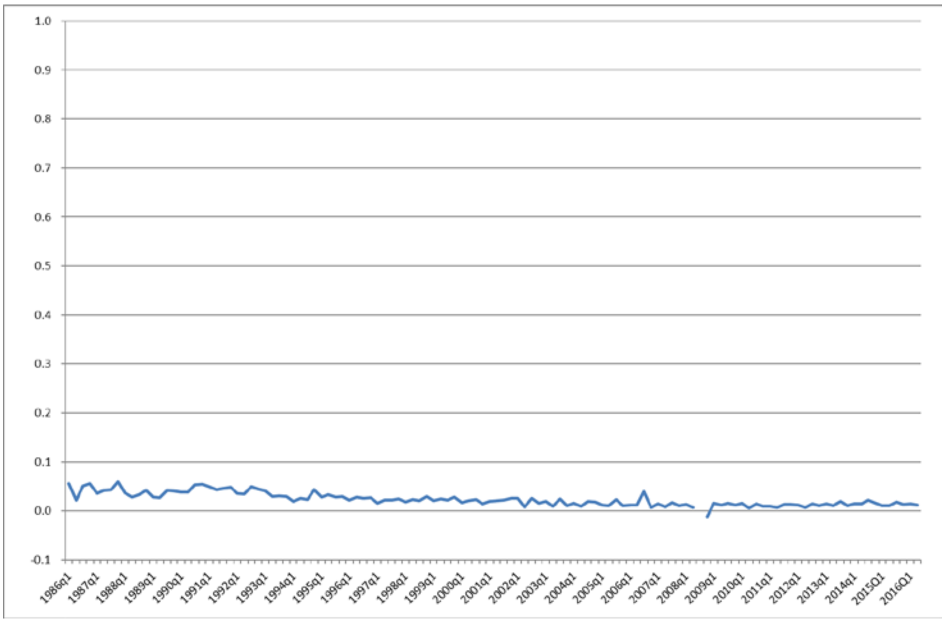
*Outliers which are beyond three times of standard deviation are excluded from our sample.

Figure 7e: Contribution of the CHF to utility in the case of setting 2.5% as a real interest rate in model (13b)



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

Figure 7f: Contribution of the CHF to utility in the case of setting 3.0% as a real interest rate in model (13b)



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