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Commodity prices and nominal exchange rates

Are they related in commodity import abundant countries?

Abstract

In this paper we investigate if commodity import prices in Korea and Japan have explaining power for their respective exchange rate. We examine this by adding a commodity import price variable to two canonical monetary models. As there has been recent research claiming that some exchange rates have embedded information about commodity prices, we also take a short glance if any direction of Granger causality exists between imported commodities' prices and exchange rates. Our results are insignificant; we cannot derive any conclusions about the relationship between the two variables studied, neither of any causal direction. The insignificant results are though results themselves; our hypotheses may be correct but not applicable on our data and econometric models. We leave this question open for other researchers to derive; if commodity prices and nominal exchange rates for commodity importing countries *are*, and if so *how*, related to each other.

Keywords: Commodity prices, commodity currency, nominal exchange rate, co-integration, Granger causality

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Table of contents

1. Introduction

The disparity between economic fundamentals and the exchange rate has been discussed thoroughly in the exchange rate literature and the results have mostly been disappointing. Ever since Meese and Rogoff (1983) first showed that none of the fundamental models could outperform the random walk, out of sample, few have been able to seriously challenge these results and shown otherwise.

Several researchers have during the past decades augmented fundamental models with purely exogenous explanatory variables to help explain exchange rates (Froot and Rogoff 1994). One such variable is commodity prices. Commodity prices are derived by the intersection of supply and demand on the world market. Most countries are not large enough to exercise any market power and can thereby not affect the prices. Hence, the prices are derived by pure market mechanisms. When the prices fluctuate it is seen as an exogenous shock to the economy (Chen 2004).

A firm relationship has been found between commodity prices and exchange rates for countries depending on commodity exports, 'commodity currencies' (Cashin, Céspedes and Sahay 2004). Recent studies incorporating a commodity variable as a complementing factor to fundamental exchange rate models have improved model fit for several modern economies that are commodity dependent (Chen 2004 and Chen and Rogoff 2003).

Studies have hitherto mainly concentrated on commodity exporting countries. In this paper we will investigate the relationship between commodity import prices and respective exchange rate in commodity importing countries. We have decided to take a closer look at Korea and Japan. They are modern economies with floating exchange rates and accountable central banks and thus market distortions should be minimized in the currency price mechanism.[1] We test if these countries' commodity imports prices can be used as an explanatory variable to improve the fit of two canonical exchange rate models.

The research on the relationship between commodity prices and exchange rates has recently taken one leap forward. For commodity exporting countries, patterns of causality have been derived to go from exchange rates to commodity prices (Chen, Rogoff and Rossi 2008). We will therefore investigate if any causal directions exist between these variables for commodity importing countries Korea and Japan.

In examining our first hypothesis, we commence by testing of which order the variables are integrated. Thereafter, we construct our models both with and without the commodity price variable. We then evaluate if the models improve when we augment them, both as a whole and the fundamental variables

[1] See *4.2 Countries*

separately. Moreover, we can study the commodity price variable itself. Already when examining the variables separately we see that our data sets seem unsuitable for our study. Our results are mostly too insignificant to allow any conclusions.

In testing our second hypothesis about causal directions, the fundamental variables are excluded due to their endogenous relation to exchange rates. Therefore we only keep the exchange rate and the commodity price variable. With these two variables we perform a test to see if any directions of causality can be determined, namely if it is clear that changes in one variable causes the other variable to react. We obtain insignificant results also here.

To our knowledge we are the first to investigate the relationship between commodity prices and exchange rates for commodity importing countries. Researchers as Chen, Rogoff and Rossi have mentioned this as an interesting topic to study, and we therefore hope to add value to the exchange rate literature. A better understanding of this relationship could possibly help policy makers in commodity importing countries in their conduct of monetary policy. Additionally, as more countries develop from exporting to importing commodities, the results can be interesting for these 'new' commodity importing countries.

The remaining part of the paper is organized as follows. Section 2 presents hypotheses and objectives. Section 3 explains the economic theory and previous research. Section 4 investigates the methodology used when constructing our parameters. Furthermore, section 5 presents the econometric methods and results. Finally, section 6 is a discussion and analysis of our results and the paper is summarized in section 7.

2. Hypotheses and objectives

The mechanisms driving exchange rates have been a concern for macroeconomic researchers for decades. Extensive research has been conducted but despite that the exchange rate puzzle is still a puzzle.[2] During recent years a 'new' variable, commodity prices, has gained attention as it has shown power in explaining exchange rates for economies with certain characteristics.

We will investigate the relationship between the nominal exchange rate and commodity prices for commodity importing countries.[3] This relationship has so far only been studied for commodity exporting

[2] There are an immense mass of papers discussing the drivers behind the exchange rate but no paper have yet found a structural model that fit both in and out of sample (in the short-run). Meese and Rogoff (1983) where the first to thoroughly show that this was the case.

[3] As proposed by Chen, Rogoff & Rossi (2008)

countries. We hope to contribute to the literature that explores the commodity-exchange rate link and to help policymakers in commodity importing countries.

There is an abundant literature about countries that show a positive relationship between their commodity exports' prices and exchange rate, 'commodity currencies'.[4] We want to investigate if the opposite relationship exists for countries that import commodities to a great extent.

Hypothesis 1: Commodity import prices have a negative correlation with the nominal exchange rate for commodity importing countries.

Recent results indicate that commodity currencies' exchange rates can predict future commodity prices, rather than the opposite (Chen, Rogoff and Rossi 2008). We have therefore conducted a causality test between the commodity price variable and the exchange rate to see if any causality exists, and if so its direction. Most of existing research assumes commodity prices to affect exchange rates in accordance with the monetary framework,[5] whereas Chen, Rogoff and Rossi (2008) have added a new point of view.

The monetary framework is not valid when testing causality. As the fundamental variables in the monetary models are endogenous they are excluded, otherwise the results cannot be interpreted.[6] We will not go through the theoretical framework of Chen, Rogoff and Rossi (2008) as it goes beyond the scope of this paper, only perform a causality test to see if any causal direction is valid for commodity importing countries.

As with our first hypothesis, we have not found any other studies testing this relationship for commodity importing countries. We therefore hope to once again contribute to the exchange rate literature.

Hypothesis 2: A causal relationship can be derived between exchange rate and commodity import prices for commodity importing countries.

3. Economic theory and previous research

Several theories explaining exchange rate movements on the basis of fundamentals have been brought forward over the recent century, all of them trying to explain the exchange rate from its time-specific circumstances. We will take a closer look at the monetary approach of the exchange rate determination as most studies conducted on commodity currencies take their theoretical reasoning from this approach.

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[4] See for example Cashin, Céspedes and Sahay (2003), Chen (2004) and Chen and Rogoff (2003).
[5] Chen (2004), Chen and Rogoff (2003), Clements and Fry (2006) are among some
[6] Even though causality should be indicated with endogenous variables, the result is difficult to interpret as the causality itself may be caused by a policy response to changes in the explanatory variable.

The monetary approach started to attract interest after the collapse of the Bretton Woods System, when formerly fixed exchange rates were floated. The monetary approach is also referred to as the asset approach since it treats the exchange rate as an asset. The exchange rate is, *de facto*, a relative price of two types of money. By treating it as an asset, the exchange rate is derived in the same way as the price of a bond or a stock. The asset approach also includes other features. Firstly, expectations will play a significant role in the determination of the exchange rate. This after money is durable, meaning that it can be held for several periods, and therefore making expectations about future exchange rate movements relevant for today's value. If expectations about future events for some reason change, today's current value of the exchange rate will also immediately change. Otherwise, there would be unexploited opportunities for profits in the foreign exchange market. Secondly, the balance of payments is treated as a solely monetary phenomenon. Thus, real factors only work through how they first affect the demand of money. Disequilibrium in the balance of payments is a reflection of disequilibrium in the money markets. Thirdly, as assets are treated as stocks, equilibrium can only be reached when supply equals demand, and there is no distinction in the mechanism if the underlying asset is either a stock or a money. Flows of assets between countries can occur, but that only mirrors the disequilibrium between money demand and money supply and therefore it must end in due course. Finally, asset prices are often looked at being determined in efficient markets and the exchange rate is not an exception. With an efficient market we mean that agents exploit all profit opportunities and push the present price to reflect all available information (Hallwood and MacDonald 2000).

3.1 Fundamental monetary models

"Under the skin of any international economist lies a deep-seated belief
in some variant of the PPP theory of exchange rates."
- *Rudiger Dornbusch and Paul Krugman (1976)*

Below we will present two widely used monetary approaches to the exchange rate that we will practice in our paper. Both models are based on the PPP theorem.[7] We will systematically go through the buildup of each step in each model to make it as easy as possible for the reader to follow.[8]

[7] The PPP theorem states that the same goods or basket of goods should sell for the same price in different countries when measured in a common currency (Hallwood and MacDonald (2000).

[8] As formerly defined, the monetary approach = the asset approach. For simplicity we will from now on consequently use the name monetary approach.

3.1.1 The flexible price model, FLMA

The flexible price monetary model appends a theory of price level determination to a PPP equation, in order to explain exchange rates. This type of model is applied in several papers; Bilson (1978), Frenkel (1976), MacDonald & Taylor (1994) and Flood and Roose (1995). We follow Hallwood and MacDonald (2000) below.

The setup of the model is two countries, home and foreign, each producing a good which are perfect substitutes implying that PPP will hold over time.[9]

$$s_t = a + p^*_t - p_t + \varepsilon_t \qquad (1)$$

The variable denoted s_t is the logarithm of foreign currency price of a unit of home currency. An increasing value therefore equals an appreciation of the home currency. The variables p_t and p^*_t are home and foreign logarithmic CPI-price levels, a is the intercept term and ε_t is the stationary disturbance term, and will be so below.[10]

Each country, except from producing a good, issues money and bonds. The bonds are perfect substitutes while the monies are non-substitutable.[11] It is assumed that asset-holders can change their portfolio instantly creating perfectly mobile capital, which implies that uncovered interest parity (UIP) holds.[12]

$$\Delta se_{t+1} = (i^* - i)_t \qquad (2)$$

where Δse_{t+1} denotes the logarithmic expected change in the exchange rate, one period ahead, and i_t and i^*_t denote home respectively foreign interest rates.

The money market consists of money demand and money supply interaction between home and foreign. The money demand has the familiar properties of:[13]

$$mD_t - p_t = a_1 y_t - a_2 i_t \qquad \text{where } a_1, a_2 > 0 \qquad (3)$$

$$mD^*_t - p^*_t = a_1 y^*_t - a_2 i^*_t \qquad (3a)$$

where mD_t is the logarithm of money demand, y_t is the logarithm of real income and i_t and p_t are denoted as earlier, and the same explanations hold for foreign.[14] Money supply is assumed to be exogenously

[9] Assuming no restrictions to trade.
[10] We use CPI as we concentrate on the Casellian view of PPP.
[11] Assuming no transaction costs and no capital controls.
[12] Meaning that the interest rate differential between home and foreign will be equalized by the change in the expected exchange rate (Hallwood and MacDolnald 2000).
[13] Typical Cagan money demand functions.

given, set by the government, and the money markets strive towards equilibrium continuously. This implies:

$$mD_t = ms_t = m_t \qquad (4)$$

$$mD^*_t = ms^*_t = m^*_t \qquad (4a)$$

By substituting (5) into (4) and subtracting the home money market connection from the foreign equation and then solving for the relative price level we get:

$$p^*_t - p_t = m^*_t - m_t - a_1(y^* - y)_t + a_2(i^* - i)_t \qquad (5)$$

Thereafter substituting price level with the expression in equation (1) we obtain the formula for the flexible price model. The exchange rate becomes a positive function of money supply and interest rate and a negative function of income, where all variables are relative rates between home and foreign:

$$s_t = a + m^*_t - m_t - a_1(y^* - y)_t + a_2(i^* - i)_t + \varepsilon_t \qquad (6)$$

As the monetary approach treats monies as assets and thereby sharing characteristics with stocks, the prices of monies are derived by expected dividends; namely the expected interest rate. As the interest rate variable, *i*, is expressed in nominal terms, it also contains information about inflation. If the domestic expected inflation is higher than the foreign, this will lead to a depreciation of the domestic currency relative to the foreign currency. This implies the change in the exchange rate is expected to be continuously the same as the expected inflation differential.

3.1.2 The sticky price model, SPMA

The sticky price model has several common features with the flexible price model. The SPMA originates from the work of Dornbusch (1976) and Frankel (1979). We will follow Frankel (1979) and Hallwood and MacDonald (2000).

The SPMA is also PPP based, and in the long-run the SPMA has the same characteristics as the FLMA. However, in the short-run the models differ due to the fact that prices are sticky, which means that the PPP assumption may be violated in the short-run:

$$\textit{Long run: } \bar{p}_t = \bar{p}^*_t - \bar{p}_t \qquad (7)$$

$$\textit{Short run: } s_t \neq p^*_t - p_t \qquad (7a)$$

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[14] We assume, for simplicity, that the income elasticity and interest rate semi-elasticity are the same between home and foreign.

where the bars define variables in the long-run. The asset markets are treated the same way as in the FLMA and are therefore again perfect substitutes and the uncovered interest parity holds. This implies that the asset markets clear continuously, but as prices are sticky in the short-run the goods markets do not clear,[15] leading to an asymmetry between goods and asset markets.

The differences between the two models can at a first glance seem small but are elementary. The interest rate i changes sign, as well as an additional variable, π, enters the equation.[16] To fully understand the SPMA we start from the beginning with the interest parity condition, keeping in mind the knowledge from equation (7):

$$d = (i^* - i)_t \qquad (8)$$

where i_t and i^*_t are defined as earlier, and d denotes the expected rate of depreciation.[17] We thereafter assume that the expected rate of depreciation is a function of the gap between the equilibrium exchange rate and the current spot rate, and of the expected long-run inflation differential between home and foreign:

$$d = -a_1(\bar{s} - s)_t + (\pi^* - \pi)_t \qquad (9)$$

where s_t and d are denoted as before, π_t and π^*_t are the present rates of expected long-run inflation for home and foreign respectively. Equation (9) states that in the short-run the exchange rate is expected to revert to its equilibrium value at a speed that is proportional to the present gap, a_1. In the long-run however, when $\bar{s} = s$,, the exchange rate is expected to change along with the long-run inflation differential, $\pi^*_t - \pi_t$. Substituting equation (8) into (9) we get:

$$a_1(\bar{s} - s)_t = [(\pi^* - \pi)_t - (i^* - i)_t] \qquad (10)$$

where all variables are denoted as prior, and will be so below. To create a complete equation for exchange rate determination we remember that if PPP holds in the long-run we get:

$$\bar{e} = (\bar{p}^* - \bar{p}) \qquad (11)$$

Then, we also recall that the Cagan money demand equation used in the FLMA holds, we get:

$$mD_t - p_t = a_1 y_t - a_2 i_t \qquad (12)$$

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15 In the long run when prices are flexible, the markets clear.

16 The interest rate variable is a real variable but is here explained by a short termed nominal interest rate, the overnight interbank rate.

17 Assuming no uncertainty as in a perfect foresight economy.

$$mD^*_t - p^*_t = a_1 y^*_t - a_2 i^*_t \qquad (12a)$$

Combining equations (12) and (12a) we get:

$$(m^* - m)_t - (p^* - p)_t = a_1(y^* - y)_t - a_2(i^* - i)_t \qquad (13)$$

Keeping in mind that in the long-run when $s = \bar{s}$ and $\bar{i}^*_t - \bar{i}_t = \pi^*_t - \pi_t$, we get:

$$\bar{s} = (\bar{p}^* - \bar{p}) = (\bar{m}^* - \bar{m}) - a_1(\bar{y}^* - \bar{y}) + a_2(\pi^* - \pi) \qquad (14)$$

Substituting equation (14) into (10) and assuming that the present equilibrium in money supplies and income levels are at their actual levels, we get a comprehensive equation for exchange rate determination, the sticky price model:

$$s_t = a + m^*_t - m_t - a_1(y^* - y)_t - a_2(i^* - i)_t + a_3(\pi^* - \pi)_t + \varepsilon_t \qquad (15)$$

where the exchange rate is a positive function of relative money supplies and the inflation differential, and a negative function of relative income and the interest rate differential, between home and foreign.

In the short-run in the SPMA prices are sticky implying that the exchange rate is expected to revert to its equilibrium value at a speed that is proportional to the present gap between the current spot rate and the equilibrium rate. In the long-run however, the exchange rate is expected to change along with the long-run inflation differential (Hallwood and MacDonald 2000).

3.2 Empirical studies of exchange rates and commodity prices

Meese and Rogoff (1983) among others conclude that these fundamental models alone are not providing satisfactory explanations of exchange rates. General problems are that most factors are endogenous and affect each other. Furthermore, it differs from time to time if the explanatory variables are exogenous or endogenous. Hence, it becomes almost impossible to determine which factors that cause the exchange rate fluctuations.

One way to overcome this problem is to add a constantly exogenous variable to the models. The variable must be both definable and measurable. Froot and Rogoff (1994) among other researchers test several such variables, but mainly conclude that they cannot improve the models.

There have been attempts to add the terms of trade to the fundamental models, but several problems have arisen when defining and measuring the variable, neither is it clearly exogenous. Instead, one can focus on only commodity prices. When trading commodities, prices are determined in a few international free markets. Further on, as prices mostly are denominated in USD, deviations in local currencies do not affect the price mechanism (Chen and Rogoff 2003).[18] Even though a country produces a significant share of world supply of a specific commodity, its market power is often mitigated; i.e. commodities can in most cases be substituted with similar commodities. Moreover, most countries are price takers as they each represent small shares of world commodity markets (Chen and Rogoff 2003). Hence commodity prices reflect a clear market price without disturbances and market imperfections. An exogenous variable that is both definable and measureable has been identified.

A country relying on commodity exports to a great extent is often referred to as a commodity economy. If there also is a strong and persistent positive relationship between the exchange rate and the commodity exports prices, the country is defined as 'commodity currency' (Cashin, Céspedes and Sahay 2004). The theory is valid for small open economies as they are unable to affect world market prices. Moreover they should have no or little capital restrictions and a floating credible exchange rate (Chen 2002). By fulfilling all these criteria, market distortions are avoided.

The phenomenon of a commodity economy is usually related to developing countries without modern industries. As these countries scarcely have floating exchange rates, inflation targets and are often subject to trade- and capital flow restrictions, developing countries are not considered satisfactory for a study of exchange rates and commodity prices (Chen and Rogoff 2003).

There are though some exceptions and a few developed economies are defined as having commodity currencies; for example Australia and New Zeeland (Chen and Rogoff 2003).[19]

3.3 Theoretical framework of exchange rates and commodity prices

Commodity prices can affect the exchange rate through different channels. Below we discuss these in both the FLMA and SPMA frameworks for commodity exporting countries. Note that we will study commodity importing countries and therefore expect opposite effects.

An increase in commodity prices or demand leads to an increase in income for commodity exporting countries. When prices in non-tradables are considered flexible, as in the FLMA, an increase in income levels leads to an exchange rate appreciation. To understand this effect we recall that in the monetary approach, changes in the explanatory variables only affect the exchange rate through its effect on money demand. Therefore, when income increases the demand for money also increases. As the FLMA model assumes a constant nominal money supply, the money markets equilibrium can only hold if home price

[18] The question we are left with is the nature of pass through; which is what we intend to investigate.
[19] Other examples of modern commodity economies are Canada, Finland and Norway (Chen and Rogoff 2003).

level falls. Given the additional assumption that PPP is strictly maintained, this can occur only if the exchange rate appreciates. Thus an increase in commodity export prices leads to an exchange rate appreciation (Hallwood and MacDonald 2000).

If non-tradable goods' prices are considered sticky, as in the SPMA, rising export prices will increase the domestic demand for non-tradable goods as the prices cannot adjust in the short run. Disequilibrium is caused between the prices of exports and non-traded goods. In order to restore equilibrium, the exchange rate will appreciate making exports more expensive on the world market. Thereby the demand of exports falls until the domestic relative price equilibrium is restored between exports and non-traded goods' prices. The net effect is an appreciation of the currency (Chen 2004).

Apparently, commodity price shocks affect the exchange rate according to both the sticky and flexible price models.

3.4 Causality

There has been extensive research on how commodity prices affect the exchange rate for commodity currencies. An opinion often expressed is that commodity prices can help explaining exchange rates (Clements and Fry 2006). In a paper by Chen, Rogoff and Rossi (2008) patterns of an opposite relationship are revealed. They claim that the causality moves from the exchange rate to commodity prices in contrast to most previous research.

To give a glance of the idea of causality we cite Gary Koop (2000):

"...time does not run backwards. That is, if event A happens before event B, then it is possible that A is causing B. However, it is not possible that B is causing A. In other words, events in the past can cause events to happen today. Future events cannot."

If unidirectional causality is indicated, it is clear that changes in one variable X causes the other variable Y to react in response, but changes in Y do not cause changes in X. If bilateral causality exists both variables X and Y affect each other simultaneously, and if no causal relationship can be derived the variables are independent of each other (Gujarati 2003).

To interpret a causal relationship, one variable must be clearly exogenous. As the variables used in the monetary models are of an endogenous nature they are excluded in the causality test (Chen, Rogoff and Rossi 2008). Causal directions are therefore only tested between commodity prices and the exchange rate. Chen, Rogoff and Rossi (2008) conclude that the causality seems to go from exchange rates to commodity prices. Thereby they find that exchange rate changes cause commodity prices to react rather than the opposite.[20]

4. Methodology

We have aimed to investigate whether commodity import prices have a negative correlation with the nominal exchange rate for countries importing commodities to a large extent and producing no or little commodities themselves.[21] Moreover, will we examine if a causal direction can be derived between these two variables. In this section we describe the methodology concerning theoretical models, choice of suitable countries, period of study and description of variables; exchange rates, commodity price indices and fundamentals. Econometric methodology and details are specified in section 5.

4.1 Models

As formerly stated; an exogenous shock is suitable when explaining exchange rate movements. Such an exogenous shock is defined in the commodity price variable. We follow the theoretical framework of Chen (2004) as the mechanisms studied are the same; namely how fluctuations in commodity prices affect small open economies' exchange rates. Chen evaluates the performance of four different models and studies the effect when a commodity price variable is added, as well as the commodity price variable itself. We have selected two of the models on the basis of general occurrence in the literature,[22] and on the number of regressors in order to avoid spurious regressions.[23] It is important to note that Chen (2004) studies commodity exporting countries, and we investigate commodity importing countries. We thereby expect the opposite sign of the commodity price variable; instead of a positive relationship between commodity prices and the nominal exchange rate we expect a negative relationship. Our models from the theoretical section, equations (6) and (15), will further on be denoted:

FLMA $$\Delta s_t = \beta_1 \Delta m_t - \beta_2 \Delta y_t + \beta_3 \Delta i_t + \varepsilon_t \quad (16)$$

FLMA(c) $$\Delta s_t = \beta_1 \Delta m_t - \beta_2 \Delta y_t + \beta_3 \Delta i_t - \beta_4 \Delta c_t + \varepsilon_t \quad (17)$$

SPMA $$\Delta s_t = \beta_1 \Delta m_t - \beta_2 \Delta y_t - \beta_3 \Delta i_t + \beta_4 \Delta \pi_t + \varepsilon_t \quad (18)$$

SPMA(c) $$\Delta s_t = \beta_1 \Delta m_t - \beta_2 \Delta y_t - \beta_3 \Delta i_t + \beta_4 \Delta \pi_t - \beta_5 \Delta c_t + \varepsilon_t \quad (19)$$

[20] Chen, Rogoff and Rossi (2008) even conclude that exchange rates predict commodity prices better than commodity futures do.
[21] If the country both imports and exports commodities it is hard determine from which variable the shock derives.
[22] Meese and Rogoff (1983) conclude that these two models are two of most frequently used models.
[23] The more repressors included the lower is the probability of maintaining a spurious regression. See Gujarati (2003) for a deeper discussion.

A *(c)* denotes that the commodity price variable is added; hence it is the augmented version of the model.

The variables *m, y, i* and π denote relative rates in their logarithmic form, whereas *s* and *c* are absolute values expressed in their logarithmic form.

When investigating if a causal direction can be derived we follow Chen, Rogoff, and Rossi (2008). The variables *m, y, i* and π are of an endogenous nature and are therefore excluded (Chen, Rogoff and Rossi 2008). We will only study the causality between the nominal exchange rate, *s*, and the commodity price variable, *c*. For econometric interpretation we follow Stavárek (2004).

4.2 Countries

We have searched for small open economies with floating exchange rates and accountable central banks. The commodity trade and production patterns should be of the opposite nature of commodity currencies, as we search for commodity importing countries. Chen, Rogoff and Rossi (2008) have previously proposed that countries in Asia might fit in well on this description.

The countries should have a floating exchange rate, in order to avoid market distortions and be applicable to the monetary approach; our theoretical framework. Moreover, the exchange rate must also have been floating for a sufficiently long time in order to obtain data without structural breaks in the currency regime. Further on, the countries should have an independent and accountable central bank with an inflation target to assure that price mechanisms are stable over time (Apel and Viotti 1998). We exclude countries without floating exchange rates, or with exchange rates that floated recently (Ilzetzki, Reinhart and Rogoff 2004). We proceed by evaluating the monetary policy conditions and conclude so far that Japan, Korea, the Philippines, Singapore and Thailand all appear to be interesting subjects for further examination.[24]

Our next step is to study the countries' respective trade patterns. As formerly defined, a commodity currency's export is commodity abundant. The economies we are interested in should instead have a commodity abundant import sector. We have therefore scanned for countries with no or little domestic production of commodities and a large part of imports consisting of commodities. If commodities are found extensively in both imports and exports we will not be able to conclude if exchange rate changes origin from changes in the commodity import or export variable.

[24] By going through all countries' respective Central Banks we evaluated their monetary policies. See 8. References Internet Sources.

Commodities are not formally defined in economic literature. We have therefore used the framework of UN COMTRADE (SITC rev 3) in order to define commodities.[25] As mentioned above, the countries we are searching for should have the opposite commodity characteristics of a commodity currency. As Australia and New Zeeland are the two most common countries referred to as commodity currencies, we will define export and import parameters for them and use as a benchmark. In *Table 1* we summarize the ratio of commodities in imports and exports, and finally the ratio of exported commodities to imported commodities.

Table 1 Commodity trade patterns 2007

Countries	**Commodity exports / total exports**	**Commodity imports / total imports**	**Commodity exports / commodity imports**
Australia	75%	25%	2,65
New Zeeland	71%	29%	2,15
Japan	10%	49%	0,24
Korea	16%	30%	0,35
Philippines	15%	30%	0,43
Singapore	19%	28%	0,78
Thailand	28%	39%	0,76

Looking at the export variable we excluded Thailand as their commodity export stands for almost a third of their total exports. The import variable gives us little useful information as Australia's and New Zeeland's commodity import levels are approximately the same as for our potential commodity importing countries except for Japan. We therefore continue by measuring the ratio of exported commodities to imported commodities. Australia's and New Zeeland's commodity exports are more than twice their commodity imports and therefore we are looking for ratios that are under 0,50. Once again Thailand fail to meet the requirement but also Singapore seems to have a too modest distinction between imports and exports of commodities to be an appropriate choice. For Japan, Korea and the Philippines the ratios are about the inverse of those of Australia and New Zeeland.

As a final test to sort out the commodity importing countries we measured the traded volumes as a ratio to GDP to make sure the economies are relying on trade. In other words the commodity importing variable must be of a significant magnitude.

[25] See *Appendix 1* for classifications.

Table 2 Commodity trade to GDP 2007

Countries	Commodity exports/ GDP	Commodity imports/ GDP
Australia	12%	4%
New Zeeland	21%	7%
Japan	2%	7%
Korea	4%	12%
Philippines	1%	2%

Australia and New Zeeland are again used as a benchmark. The Philippines do not meet the requirement as their commodity import to GDP is only 2%. Korea is a perfect duplicate of Australia's trade patterns but with an opposite direction, and is therefore suitable as a commodity importing economy. Japan has a low commodity export to GDP ratio, which is an appealing feature, as well as a relatively high commodity import to GDP ratio. Although Japan's commodity import ratio to GDP is less than Korea's, Japan matches the benchmark best in all other categories and we therefore also acknowledge Japan as a suitable example of a commodity importing economy.[26]

4.3 Period of study

For Japan our period of study starts in Q1 1990 since Bank of Japan's (BoJ) import commodity index is measured since then.[27] This index is used as a variable in our models and will be further discussed below. The Yen has been floating consequently during this period. Further on, we use data from Q3 1998 for Korea since the won was floated on July 1st 1998. Both time series end in Q4 2008, which is the most recent quarter with obtainable data. We have used quarterly data instead of monthly data to avoid short run disturbances.[28]

4.4 Exchange rates and commodity anchors

We have chosen the nominal exchange rate for our study, again following both Chen (2004) and Chen, Rogoff and Rossi (2008). As commodity prices are denominated in USD, and thereby a nominal variable,

[26] We acknowledge that Japan is a rather large economy, but as Japan is one country of many countries importing commodities we argue that their market power is mitigated. We refer interested readers to International Trade Center's homepage (ITC) for a trade statistic overview.

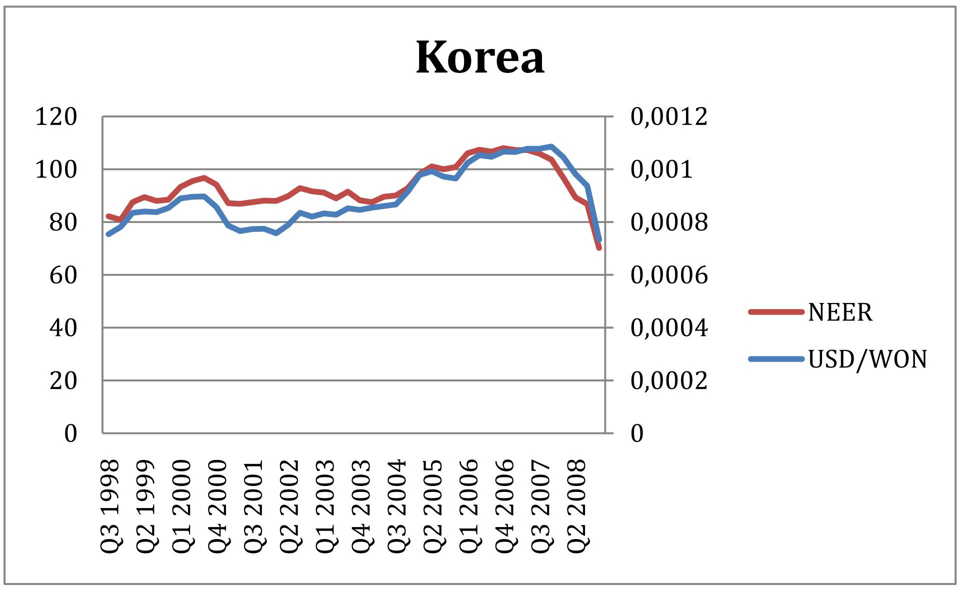
[27] http://www.boj.or.jp/en/theme/research/stat/pi/oci/index.htm

[28] Chen, Rogoff and Rossi (2008) conclude that the same results are obtained from monthly data and quarterly data. We therefore use quarterly data to avoid short run disturbances.

it seems reasonable to express the exchange rate in nominal terms as well.[29] Nominal effective exchange rate (NEER) is an average of bilateral nominal exchange rates, weighted after the domestic trade portfolio. Hence, the NEER should be directly affected by commodity price changes if our first hypothesis is valid.[30] This measurement seems reliable when determining the value of a currency as it should not be disturbed by shocks to single anchor currencies or economies, as could be the case if only one anchor is used.

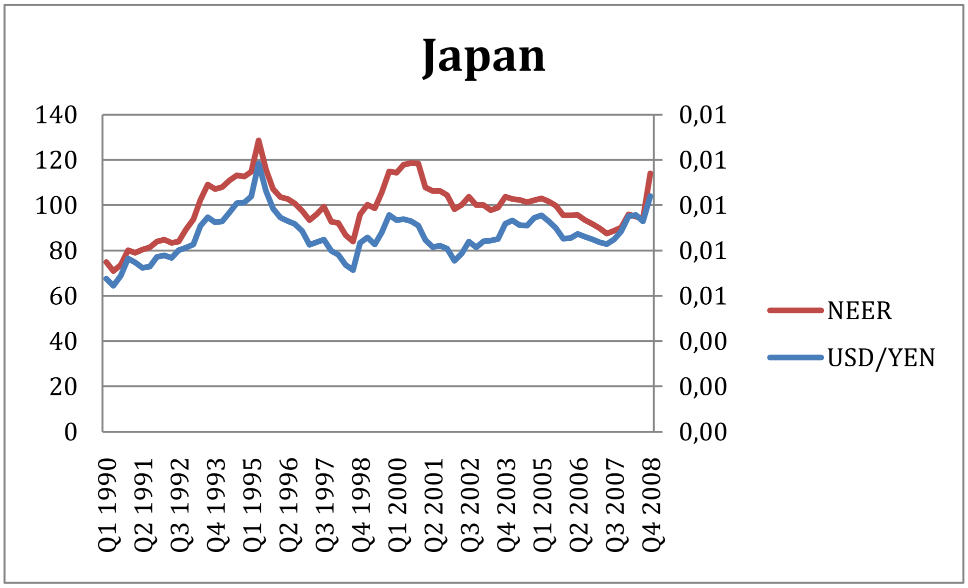
It is preferable and simpler to measure currencies and commodities to the same anchor. As commodities are denominated in USD we plot the NEER and USD bilateral exchange rates in order to determine if we can use the bilateral exchange rate instead.

Figure 1 NEER[31] and bilateral exchange rate to USD for Korea



[29] As the countries studies all have inflation targets implemented by independent central banks, we avoid the possible problem of disturbing inflation differentials.
[30] If commodity prices rise and our hypothesis is valid, the domestic currency will depreciate relative to the countries exporting commodities, which are included in the NEER.
[31] NEER is expressed as an index and is therefore not measured on the same scale as the bilateral exchange rate. Both the NEER and the bilateral exchange rate is measured as foreign currency per domestic currency, e*/e.

Figure 2 NEER and bilateral exchange rate to USD for Korea



For both Japan and Korea the figures exhibit substantial co-movement between the NEER and the bilateral USD exchange rate. We therefore conclude that the bilateral dollar exchange rate should be a representative measurement for the strength of Korea's and Japan's respective currencies. Our results should neither be distorted by shocks to the USD or US economy if we use the bilateral exchange rate. Moreover, as commodity prices are denominated in USD, fluctuations in the USD should not disturb the prices of commodities. If the bilateral exchange rates were significantly different from the NEERs, the commodity prices would be disturbed by the USD fluctuations. We choose to use the bilateral nominal exchange rates USD/Yen and USD/Won and measure commodities in USD in our study and conclude from our graphical analysis that our results should be reliable.

4.5 Commodity price indices

To measure the impact of commodity import prices on Japan's and Korea's respective exchange rate we follow Chen (2004). We require variables reflecting each country's import pattern in terms of commodity prices.

For Japan we use a commodity index from BoJ.[32] The index is the weighted average[33] of prices for Japan's 17 most imported commodities. The weights are revised every fifth year in order to follow the

[32] http://www.boj.or.jp/en/theme/research/stat/pi/oci/index.htm
[33] geometric mean

actual trade pattern of Japan. The commodities are denominated in nominal USD prices and indexed with 2005 as base year.[34]

For Korea we found no such index and therefore constructed a similar variable ourselves, following the BoJ methodology.[35] We used data from UN COMTRADE (SITC rev 3) to extract volumes of imported commodities. Thereafter, we took world market commodity price indices from IMF IFS database, denominated in USD, for each relevant commodity group. As the classifications are different in the UN COMTRADE and IMF IFS, we revised[36] the commodity groups in the UN COMTRADE until we could construct new commodity groups comparable to the existing price indices from the IMF.[37] With these new commodity groups we calculated weights for the years 2000 and 2005. By matching these weights with the price indices we then constructed two weighted[38] price indices. As the time series we study for Korea start in 1998 we used the year 2000 weights for 1998-2004, and the 2005 weights for 2005 – 2008. The series were then linked together following methodology from BoJ.[39]

Both indices for Japan and Korea were then transformed to quarterly data by averaging three month values. The base 2005 was set to 1 instead of 100 to be of the same scale as other variables described below.

4.6 Other variables

We use data from IMF IFS for nominal GDP, (y^* and y) and for CPI, (π^* and π), both expressed as indices with 2005 as base. The nominal money supplies (m^* and m) and the nominal exchange rates (s) are indexed with an average of all the quarters of 2005 as base to make it easily comparable to GDP and CPI indices. All variables hitherto discussed are ratios of indices with the same base year. Thereby we obtain values of the same proportion, allowing us to study them in a diagram with one common scale. The interest rate variable (i^* and i) is the overnight interbank rate. The interest rate is not transformed to an

34 See *Appendix 2* for weights.
35 http://www.boj.or.jp/en/type/exp/stat/exoci.htm
36 We divided the general groups until we could match the commodities with the price indices.
37 The commodity variable for Korea might not be as well composed as the one for Japan as we used data from different sources that use different classifications.
38 Geometric mean
39 2005 base linked index =2000 base index * link coefficient

$$\text{Link coefficient} = \frac{\text{annual average index in 2005 on the 2005 base } (= 100)}{\text{annual average index in 2005 on the 2000 base}}$$

index as it is a ratio and not an absolute value.[40] All relative ratios are US values divided by domestic values.

5. Econometric methods and results

Our first hypothesis is tested by investigating the behavior of two monetary models when a commodity import price variable is added. We will also study the characteristics of the commodity price variable itself. Our second hypothesis concerns the nominal exchange rate and the commodity price variable and possible causal relations among the two.

5.1 Hypothesis 1

We examine how two models behave when commodity prices are added as an explanatory variable. We construct the models with stationary variables in order to avoid spurious regressions and therefore begin by studying the variables separately.

5.1.1 Studies of the variables

All variables must be studied separately in order to determine whether they are stationary or not. If the variables are non-stationary in their level form, one has to differentiate them until stationary.[41] Otherwise results might appear to be statistically significant, but in fact they could be inadequate and just by a co-incidence appear to be of high explanatory power. The results then become nonsense (Gujarati 2003).

We start by plotting the variables over time. By visual inspection, we suspect a time trend to be found in all variables except for Korea's exchange rate, Korea's relative inflation rate and Japan's relative inflation rate.[42] See *Appendix 3*.

We proceed by investigating if the variables are stationary or non-stationary. The unit root test developed by Dickey and Fuller (DF) is performed for all variables; with trend for variables were we suspect a trend is likely to be found, and without trend for the remaining three variables (Gujarati 2003). The equations with and without trend look as follows:

[40] It is worth noting that neither is the exchange rate an absolute value. The reason is that the ratio is always fixing the denominator. Transforming it to an index with 2005 as base does not change the movements of the variable but is then denominated in a scale similar to the other variables. We concluded there is no reason to make an index of the interest rate as both the numerator and denominator are allowed to fluctuate freely and both of them are already ratios.

[41] A variable is said to be stationary if its mean and variance are constant. See Gujarati 2003 for a deeper discussion of stationary variables.

[42] A time trend is suspected if a slow long run evolution seems to be predictable.

DF without trend:

$$Y_t = \beta_1 + \beta_2 Y_{t-1} + \varepsilon_t \qquad (20)$$

$H_0: \beta_2 = 1$

$H_1: \beta_2 < 1$

DF with trend:

$$Y_t = \beta_1 + \beta_2 T + \beta_3 Y_{t-1} + \varepsilon_t \qquad (21)$$

$H_0: \beta_3 = 1$

$H_1: \beta_3 < 1$

In both cases H_0 is rejected if $t_{obs} < \tau_{crit}$, which implies the time series is stationary and does not contain a unit root. The *t* value of the coefficient of Y_{t-1} follows the τ statistic and not the regular t distribution (Gujarati 2003).

ε_t is a white noise error term with zero mean and constant variance, σ^2. It is serially uncorrelated, hence it is stationary and purely random (Gujarati 2003).

If the error term ε_t in fact is serially correlated a number of lagged values of the difference should be added to the equation, in order to include enough terms so the error term ε_t becomes serially uncorrelated (Gujarati 2003). We proceed by performing this augmented version of the DF test, called ADF, for all variables where H_0 cannot be rejected in the normal DF test. A number of lagged differentiated terms are added and the equations from above become:

ADF without trend:

$$Y_t = \beta_1 + \beta_2 Y_{t-1} + \sum_{i=1}^{m} \alpha_i \Delta Y_{t-i} + \varepsilon_t \qquad (22)$$

$H_0: \beta_2 = 1$

$H_1: \beta_2 < 1$

ADF with trend:

$$Y_t = \beta_1 + \beta_2 T + \beta_3 Y_{t-1} + \sum_{i=1}^{m} \alpha_i \Delta Y_{t-i} + \varepsilon_t \qquad (23)$$

$H_0: \beta_3 = 1$

H_1: $\beta_3 < 1$

The decision rule is the same as for the normal DF test; H_0 is rejected if $t_{obs} < \tau_{crit}$, which implies the time series is stationary and does not contain a unit root.

We test for one to four lagged values, m=1, 2, 3 and 4. It seems unlikely that more than four lags should be included.[43] The optimal number of lags of those tested, m, is computed by Akaike's Information Criteria:

$$AIC = e^{2k/n} \frac{\sum \hat{\varepsilon}_i^2}{n} = e^{2k/n} \frac{RSS}{n} \qquad (24)$$

The lowest obtained AIC value is the most representative test result and is shown together with the results of the normal DF test in *Appendix 4*.[44]

Our results from the unit root tests are that none of the variables in their level form are stationary; hence all variables contain at least one unit root. We can therefore not evaluate our models with variables in level without running the risk of obtaining a spurious regression.

We continue by performing the same tests for the variables in their first differences. The equations without trend will now be without a constant. Those with trend, in their level form, will be with only a constant and without trend in first differences.

DF without trend:

$$\Delta Y_t = \beta_1 \Delta Y_{t-1} + \varepsilon_t \qquad (25)$$

H_0: $\beta_1 = 1$

H_1: $\beta_1 < 1$

DF with trend:

$$\Delta Y_t = \beta_1 + \beta_2 \Delta Y_{t-1} + \varepsilon_t \qquad (26)$$

H_0: $\beta_2 = 1$

H_1: $\beta_2 < 1$

[43] We find it unlikely that commodity prices one year ago should affect the spot exchange rate.
[44] Complete data will be presented on demand.

ADF without trend:

$$\Delta Y_t = \beta_1 \Delta Y_{t-1} + \sum_{i=1}^{m} \alpha_i \Delta^2 Y_{t-i} + \varepsilon_t \quad (27)$$

$H_0: \beta_1 = 1$

$H_1: \beta_1 < 1$

ADF with trend:

$$\Delta Y_t = \beta_1 + \beta_2 \Delta Y_{t-1} + \sum_{i=1}^{m} \alpha_i \Delta^2 Y_{t-i} + \varepsilon_t \quad (28)$$

$H_0: \beta_2 = 1$

$H_1: \beta_2 < 1$

We can only reject H_0 for Korea's GDP, evidently it appears to be I(1) and therefore stationary in its first difference.

We proceeded by testing the second differences for all other variables. Now the constant is also removed in the equations for variables with trend. Thereby there is no distinction between variables with and without a trend.

DF with and without a trend:

$$\Delta^2 Y_t = \beta_1 \Delta^2 Y_{t-1} + \varepsilon_t \quad (29)$$

$H_0: \beta_1 = 1$

$H_1: \beta_1 < 1$

ADF with and without trend:

$$\Delta^2 Y_t = \beta_1 \Delta^2 Y_{t-1} + \sum_{i=1}^{m} \alpha_i \Delta^3 Y_{t-i} + \varepsilon_t \quad (30)$$

$H_0: \beta_1 = 1$

$H_1: \beta_1 < 1$

We can reject H_0 for all variables tested, except for Korea's exchange rate. The variables are concluded to be I(2), hence their second differences are stationary. For the last variable, Korea's exchange rate, we perform the unit root tests for the third difference:

DF with and without trend:

$$\Delta^3 Y_t = \beta_1 \Delta^3 Y_{t-1} + \varepsilon_t \quad (31)$$

H_0: $\beta_1 = 1$

H_1: $\beta_1 < 1$

ADF with and without trend:

$$\Delta^3 Y_t = \beta_1 \Delta^3 Y_{t-1} + \sum_{i=1}^{m} \alpha_i \Delta^4 Y_{t-i} + \varepsilon_t \quad (32)$$

H_0: $\beta_1 = 1$

H_1: $\beta_1 < 1$

We can now reject H_0 and thereby conclude that Korea's exchange rate is an I(3), its third difference is stationary.

5.1.2 Studies of the models

As all our variables contain at least one unit root, they are all integrated of a higher order than zero. We must therefore test for co-integration in order to avoid a spurious regression. The implication here is that if the residual ε_t is stationary, and thereby does not contain a unit root, the variables share a stochastic trend and have a long-run linear equilibrium. The variables are then said to be co-integrated and we can construct a model with differentiated non-stationary variables without obtaining a spurious regression (Gujarati 2003). The order of integration determines in which difference the variable should be denoted in the models.

Our models look as follows:

Korea

FLMA $\quad \Delta^3 s_t = \beta_1 \Delta^2 m_t - \beta_2 \Delta y_t + \beta_3 \Delta^2 i_t + \varepsilon_t \quad$ (33)

FLMA(c) $\quad \Delta^3 s_t = \beta_1 \Delta^2 m_t - \beta_2 \Delta y_t + \beta_3 \Delta^2 i_t - \beta_4 \Delta^2 c_t + \varepsilon_t \quad$ (34)

SPMA $\quad \Delta^3 s_t = \beta_1 \Delta^2 m_t - \beta_2 \Delta y_t - \beta_3 \Delta^2 i_t + \beta_4 \Delta^2 \pi_t + \varepsilon_t \quad$ (35)

SPMA(c) $\quad \Delta^3 s_t = \beta_1 \Delta^2 m_t - \beta_2 \Delta y_t - \beta_3 \Delta^2 i_t + \beta_4 \Delta^2 \pi_t - \beta_5 \Delta^2 c_t + \varepsilon_t \quad$ (36)

Japan

FLMA	$\Delta^2 s_t = \beta_1 \Delta^2 m_t - \beta_2 \Delta^2 y_t + \beta_3 \Delta^2 i_t + \varepsilon_t$	(37)
FLMA(c)	$\Delta^2 s_t = \beta_1 \Delta^2 m_t - \beta_2 \Delta^2 y_t + \beta_3 \Delta^2 i_t - \beta_4 \Delta^2 c_t + \varepsilon_t$	(38)
SPMA	$\Delta^2 s_t = \beta_1 \Delta^2 m_t - \beta_2 \Delta^2 y_t - \beta_3 \Delta^2 i_t + \beta_4 \Delta^2 \pi_t + \varepsilon_t$	(39)
SPMA(c)	$\Delta^2 s_t = \beta_1 \Delta^2 m_t - \beta_2 \Delta^2 y_t - \beta_3 \Delta^2 i_t + \beta_4 \Delta^2 \pi_t - \beta_5 \Delta^2 c_t + \varepsilon_t$	(40)

A (*c*) implies the commodity variable is included in the equation.

We commence by computing the Durbin Watson d-statistic for the models and test for co-integration. The test is as follows:

$H_0: d = 0$

$H_1: d > 0$

If $d_{obs} > d_{crit}$ H_0 can be rejected and the time series are co-integrated. [45]

A rule of thumb when using the Durbin-Watson d-statistic is that d_{obs} should be higher than the R^2 value.[46] If this is not the case, one should be suspicious about obtaining a spurious regression (Gujarati 2003). All obtained d-values are significantly higher than the critical value, and also far above the adjusted R^2. We conclude that the Durbin-Watson test shows co-integration for all four models for both countries.

To further test for co-integration we also perform the Engle-Granger co-integration test. The test is similar to the Dickey-Fuller test for a unit root, but instead of the variables the residuals ε_t are tested:[47]

$$\Delta\hat{\varepsilon}_t = \beta_1 \hat{\varepsilon}_{t-1} + error_t \qquad (41)$$

$H_0: \beta_1 = 0$

$H_1: \beta_1 < 0$

Reject H_0 if $t_{obs} < \tau_{crit}$. If H_0 can be rejected the time series are co-integrated.

[45] The standard DW test is d=2, and the test is of d~2(1-p) where p=1 implies a unit root, hence d=0. See Gujarati (2003) for further discussion.
[46] We consequently use the adjusted R^2 value as it takes into account the number of explanatory variables included in the equation.
[47] One can test the DF in two ways, in level the hypothesis is β_2=1, in first difference β_2 =0, we refer interested readers to Gujarati (2003).

We reject the null hypothesis of no co-integration in all eight cases. We conclude from these two tests that there is evidence of co-integration in our models. See *Appendix 5* for co-integration tests results.

We can now rely on the result from our regressions and proceed by examining the effect of adding a commodity price parameter to the monetary models. The models are summarized in *Appendix 6*.

We expect the commodity parameter to be negative; as our hypothesis is that an increase in commodity prices will lead to a depreciation of the two currencies studied.

The commodity variable is in three of four cases positive. In all cases the coefficient of the variable is insignificant and we can therefore not conclude anything about its nature.

The models in general perform rather poorly. The obtained adjusted R^2 is very low for Japan and somewhat better for Korea, though still low. The R^2 does not increase significantly when we add the commodity parameter; hence *c* does not seem to complete the models. The coefficients of fundamental variables are insignificant for Korea in all cases except for the relative interest rate, *i*, but only in two of four cases is the sign as expected for *i*. For Japan relative money supply, *m*, is significant and of right sign in all four cases. The relative interest rate, *i*, is significant and of right sign in two cases, and *p* is significant but of the wrong sign in two cases. The significant variables do not clearly become more significant or change to the expected signs when *c* is added. In conclusion, the models perform poorly and are not improved when the commodity variable is added.

It should be noted that all variables are co-integrated in all eight tested equations and we have four to six variables in each equation. Thereby a long-run relationship does exist among these variables. Co-integration results are not affected when *c* is added; neither stronger nor weaker.

5.2 Hypothesis 2

We will investigate if any causality can be indicated between commodity prices and exchange rates following Chen, Rogoff and Rossi (2008) when defining variables and Stavárek (2004) for econometric interpretation. Returning to our previous argument the fundamental variables are here excluded, as they are endogenous. Of the former explanatory variables only the commodity parameter is kept as it is considered purely exogenous.

We investigate if any unidirectional causality can be indicated, in other words if it can be determined that changes in one variable causes the other variable to react. We use the Granger causality test for this purpose. It is here important to note that Granger causality is reliable when we can prove that the variables are stationary (Gujarati 2003). This was proved by the unit root tests in *Hypothesis 1*. We will therefore proceed with the following variables for Korea and Japan respectively:

Korea

$\Delta^3 s$ and $\Delta^2 c$

Japan

$\Delta^2 s$ and $\Delta^2 c$

First we investigate if the two variables are co-integrated using the same tests as in *Hypothesis 1*:

Korea

$$\Delta^3 s_t = \gamma \Delta^2 c_t + \varepsilon_t \qquad (42)$$

Japan

$$\Delta^2 s_t = \gamma \Delta^2 c_t + \varepsilon_t \qquad (43)$$

Our results from the Durbin-Watson and Engle-Granger co-integration tests are that these two variables are co-integrated for both countries; see *Appendix 7*. When performing the Granger causality test we must then take into account the co-integrating vector (Stavárek 2004).

The Granger causality equations formed are:

Korea

$$\Delta^4 s = \alpha_0 + \delta_1(\Delta^3 s_{t-1} - \gamma \Delta^2 c_{t-1}) + \sum_{i=1}^{k} \alpha_{1i} \Delta^4 s_{t-1} + \sum_{i=1}^{k} \alpha_{2i} \Delta^3 c_{t-1} + \varepsilon_{1t} \qquad (44)$$

$$\Delta^3 c = \beta_0 + \delta_2(\Delta^3 s_{t-1} - \gamma \Delta^2 c_{t-1}) + \sum_{i=1}^{k} \beta_{1i} \Delta^4 s_{t-1} + \sum_{i=1}^{k} \beta_{2i} \Delta^3 c_{t-1} + \varepsilon_{2t} \qquad (45)$$

Japan

$$\Delta^3 s = \alpha_0 + \delta_1(\Delta^2 s_{t-1} - \gamma \Delta^2 c_{t-1}) + \sum_{i=1}^{k} \alpha_{1i} \Delta^3 s_{t-1} + \sum_{i=1}^{k} \alpha_{2i} \Delta^3 c_{t-1} + \varepsilon_{1t} \qquad (46)$$

$$\Delta^3 c = \beta_0 + \delta_2(\Delta^2 s_{t-1} - \gamma \Delta^2 c_{t-1}) + \sum_{i=1}^{k} \beta_{1i} \Delta^3 s_{t-1} + \sum_{i=1}^{k} \beta_{2i} \Delta^3 c_{t-1} + \varepsilon_{2t} \qquad (47)$$

The co-integrating vector is denoted δ_1 and δ_2 and $\delta_1 \neq \delta_2$. Equations (42) and (43) can be written as:

$$\varepsilon_t = \Delta^3 s_t - \gamma \Delta^2 c_t \qquad (48)$$

$$\varepsilon_t = \Delta^2 s_t - \gamma\Delta^2 c_t \quad (49)$$

Hence

$$\varepsilon_{t-1} = \Delta^3 s_{t-1} - \gamma\Delta^2 c_{t-1} \quad (50)$$

$$\varepsilon_{t-1} = \Delta^2 s_{t-1} - \gamma\Delta^2 c_{t-1} \quad (51)$$

By obtaining the residual from the co-integration equations above and lag it one period we obtain the co-integrating parameter and a Granger causality test can be performed through equations (44) to (47). Co-integration implies $|\delta_1|+|\delta_2| > 0$. The hypothesis tested for (44) and (46) is:

$$H_0\text{: } \alpha_{21} = \alpha_{22} = \ldots = \alpha_{2k} = 0 \text{ and } \delta_1 = 0$$

$$H_1\text{: } \alpha_{21} \neq \alpha_{22} \neq \ldots \neq \alpha_{2k} \neq 0 \text{ and } \delta_1 \neq 0$$

H_0 is rejected if $F_{obs} > F_{crit}$ and $t_{obs} > t_{crit}$ for δ_1, which implies unidirectional causality running from commodity prices, $\Delta{*}c$, to the exchange rate, $\Delta{*}s$. The reason is the lagged terms of the added explanatory variable are different from zero and hence significant and belonging in the equation, as well as the co-integrating parameter being different from zero and also belonging in the equation. The hypothesis tested for (46) and (48) is the reverse:

$$H_0\text{: } \beta_{11} = \beta_{12} = \ldots = \beta_{1k} = 0 \text{ and } \delta_2 = 0$$

$$H_1\text{: } \beta_{11} \neq \beta_{12} \neq \ldots \neq \beta_{1k} \neq 0 \text{ and } \delta_2 \neq 0$$

The decision rules and interpretation are the same as for equations (45) and (47);[48] but instead unidirectional causality runs from the exchange rate, $\Delta{*}s$, to the commodity price variable, $\Delta{*}c$. If both hypotheses are rejected the causality is bilateral and runs in both directions. If both hypotheses are accepted the variables are independent of each other. We choose to test for one to four lags, $k=4$, as we did in the ADF test; we see no reason why more than one year time difference should be included. Results are summarized in *Appendix 8*.

We can reject the null hypothesis in one case; with one lag included unidirectional causality goes from commodity prices to exchange rate for Korea.

[48] δ_2 instead of δ_1 is tested to be different from zero.

6. Discussion of results

Previous research on fundamental exchange rate determination has often had insignificant results as an outcome. It is therefore not a surprise to us we cannot obtain significant results concerning the relationship between exchange rates and commodity prices.

Already when we investigate the variables one by one problems arise. One parameter appears to be an I(3) which is not a reliable result. Most of our fundamental parameters should be expected to be I(1) or perhaps I(2), e.g. inflation is a parameter expected to be an I(2) as it is a derivative.[49] As one variable is clearly integrated of a too high order and several others might be so too, we suspect that our data is not optimal for this study. Despite this, we continue with all tests we intended to perform keeping in mind that our basic data might be inappropriate for the study.

The performance of the two models do not improve as we add the commodity import price variable, the coefficients of fundamentals do not become more correct or significant and the commodity variable itself is insignificant and for the most part of the wrong sign. The models perform somewhat better for Korea than for Japan in terms adjusted R^2, but the coefficients of the variables are overall more significant for Japan.

As far as we know, no such studies have been performed to date and therefore it is possible that our hypotheses are true, but not applicable on our choice of data and/or theoretical framework. Further research is therefore needed.[50]

Japan being one of the world's largest economies could imply potential problems as the theoretical framework is restricted to small open economies. Japan may therefore have market power over certain commodity prices. I.e. the largest component in Japan's commodity price index is crude oil (66%) and Japan is the second largest world importer of crude oil, next to the US. It is therefore possible that Japan holds market power over the price of crude oil.[51] On the other hand, several papers address the connection between oil price and Japan's economy and it seems as the oil price effects Japan more than Japan effects the oil price.[52]

Moreover, Japan faced a financial crisis during the 1990's. Looking at the yen path we see a rather strange behavior during the 90's. Korea was hit by the Asian crisis in 1997, which probably put their

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[49] We refer the discussion of the connection between econometric and economic theory to Rickard Sandberg and Gujarati (2003).

[50] As BoJ measures commodity import prices they obviously consider it having an effect on their economy.

[51] http://www.indexmundi.com/g/r.aspx?t=50&v=93&l=en

[52] See i.e. Byung Rhae Leea, Kiseok Leeb and Ronald A. Ratti (2001), Mitsuhito Ono (2004).

economy out of equilibrium in the beginning of the sample period. During periods of crises, economic models usually perform poorly as the real economy is out of equilibrium. The fact that both our data sets cover periods of crises can be one explanation for our insignificant results as well as why we obtain variables that are integrated of an unusually high order.

Another reason for Korea's poor model fit can be due to its recent transformation from a developing country to a developed country. Therefore Korea may have had some developing country features in the beginning of out data period. For instance it is somewhat unclear if the Bank of Korea is totally independent and they have only had a floating exchange rate for ten years.

We have not taken into account what trade restrictions might exist in the countries respectively. We have simply treated the countries as open economies since their traded volumes are significant shares of GDP and economic features, through central banks and exchange rate regimes, are in accordance with modern open economies.

Oil is the heaviest commodity in both indices, representing more than 50% of commodity imports for both Korea and Japan. Therefore it is worth mentioning the oil market being of a cartel nature. Some oil producing countries set the supply according to the world market price, and therefore it cannot be considered a purely exogenous variable. But on the other hand this should not affect the importing countries as they are most likely to be price takers and have no choice but to import the needed amount of oil.

Another possible reason for obtaining insignificant results can be due to the magnitude of the potential commodity import market. A commodity exporting country can in theory export to almost seven billion people. A commodity importing country's import market for certain commodities, e.g. food, is probably restricted to its own population, which is about 130 million for Japan and 50 million for Korea.[53] For other commodities, e.g. iron, the import market is of a larger magnitude as it is a commodity that can be refined and exported.

When testing for causality we neither obtained significant results except for in one case. In this one case it was not in the same direction as Chen, Rogoff and Rossi (2008) found. We consider this result too weak to interpret in an analysis. As far as we are concerned no such studies have been performed before, and further research seems to be needed.[54] The absence of a causal relationship might be due to the same reasons as mentioned above.

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[53] See *Table 1 and 2* for magnitude of commodity imports.

[54] Tests of causality directions between oil price and the Yen have been performed, but not between the whole commodity index and the Yen to our knowledge. For Korea we have found no such studies at all.

Concluding, we cannot show that any relationship is clear between commodity import prices and the Japanese or Korean nominal exchange rate during the last 20 and 10 years respectively. Moreover, we test for possible causality but obtain insignificant results. We therefore regard this topic given our data and methods as a dead end, but hope that other researchers sometime will explore it deeper to prove us being either right or wrong.

7. Conclusion

We were not able to improve the fit of the flexible price model or the sticky price model by adding a commodity import price variable. Neither can we say anything more about the commodity price variables themselves.

At an early stage we suspected that our datasets were non-optimal for our study as at least one variable was integrated of a too high order to be in line with economic theory. Despite this, we fulfilled our assignment and performed the tests we intended to, but significant results were hard to obtain.

The crisis in Japan in the early 1990s might disturb the data by pushing the economy out of equilibrium. Furthermore, Japan might have some market power over commodity prices due to its share size adds a further level of complexity. Moreover, the Asian Crisis in 1997 could explain the insignificant results for Korea.

Another explanation can be that the magnitude of the importing sector is not always equivalent to the magnitude of the exporting sector. Thereby a possible shock in commodity prices might not have the same impact on the exchange rates for commodity importing countries as for exporting countries.

When controlling for possible causal directions, we once again could not retrieve reliable results. We suspect the reason being of a similar kind as those described above.

In accordance with most exchange rate research we failed to obtain significant results, which however must be regarded a result in its own right. As we are the first to perform these two studies, further research – both as regards modeling and collection of data - is needed to be able to draw more firm conclusions of the relationship between commodity import prices and nominal exchange rates for commodity importing countries.

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C. Data sources

Commodity Price Indices were taken from IMF IFS database.

Commodity trade weights and classifications were taken from UN Comtrade SITC rev 3.

NEER for Japan was taken from IMF IFS database and for Korea from Bank for International Settlement.

Bilateral exchange rates to USD, GDP, M0 and CPI were taken from IMF IFS database.

Overnight Interbank Rates were taken from OECD.

Methodology for commodity price index was taken from Bank of Japan.

9. Appendices

Appendix 1 – Commodity classifications

SITC rev 3 code	Name
0	Food and live animals
1	Beverages and tobacco
2	Crude materials, inedible, except fuels
3	Mineral fuels, lubricants and related materials
4	Animal and vegetable oils, fats and waxes
6.7	Iron and steel
6.8	Non-ferrous metals
9.7	Gold, nonmonetary excl ores

Source: UN Comtrade SITC rev. 3

Appendix 2 – Commodity index weights

Japan

Japan commodity index	
Commodity	Weight 2005
Crude oil	66,0
Copper	6,8
Aluminum	4,6
Nickel	2,5
Molybdenum	1,8
Platinum	1,4
Gold	0,9
Rhodium	0,5
Cotton	0,2
Lumber	1,2
Natural rubber	2,1
Corn	2,1

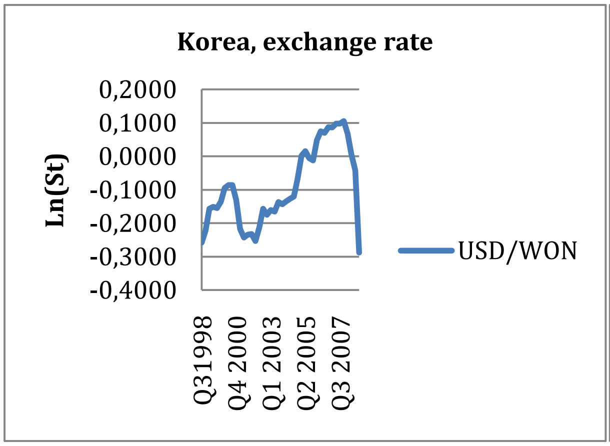
Soybeans	1,7
Wheat	1,0
Coffee	1,8
Lean hog	3,7
Live cattle	1,7
Total	100,0

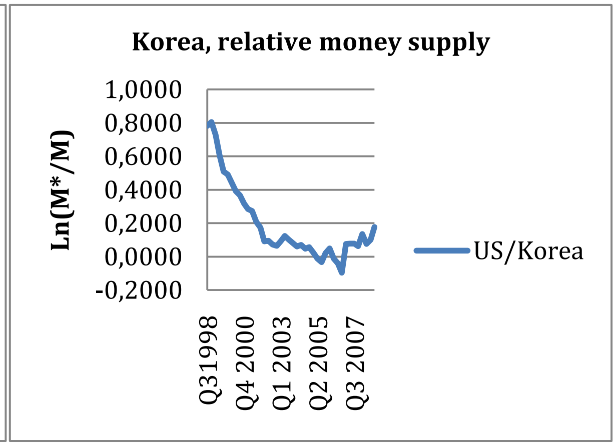
Source: Bank of Japan

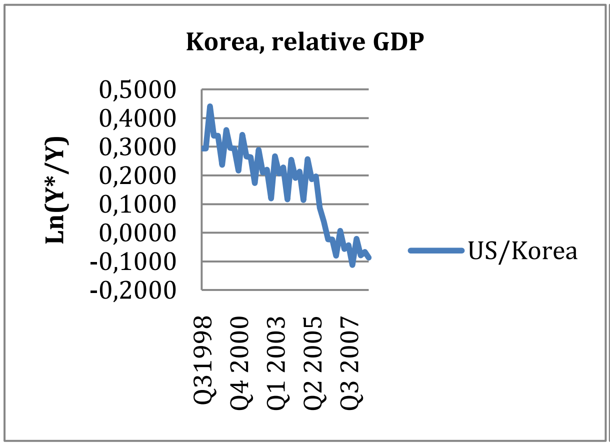
Korea

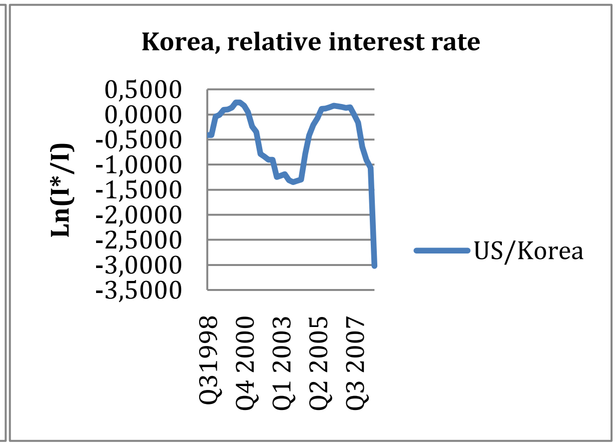
Korea commodity index		
Commodity	Weight 2000	Weight 2005
Aluminum	3,4	3,1
Coal	3,8	5,3
Copper	3,6	4,4
Fish	1,9	1,7
Gasoline	45,6	43,5
Gold	4,0	0,9
Iron	8,6	13,9
Iron ore	3,6	4,2
Maize	1,7	1,2
Natural gas	9,5	10,7
Nickel	1,0	1,2
Petroleum	8,6	7,4
Pulp	3,0	1,5
Softwood	1,6	1,1
Total	100,0	100,0

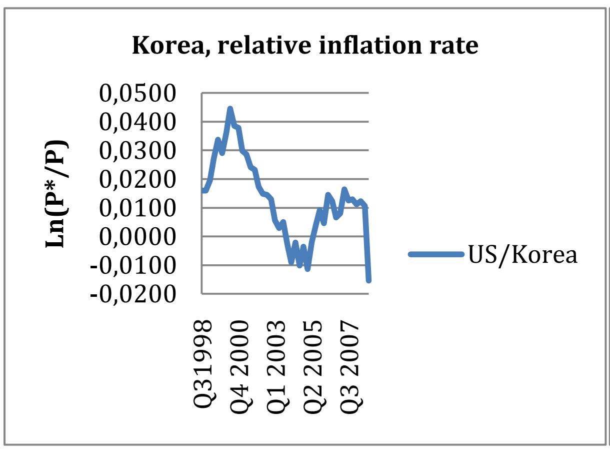
Appendix 3 – Graphical analysis

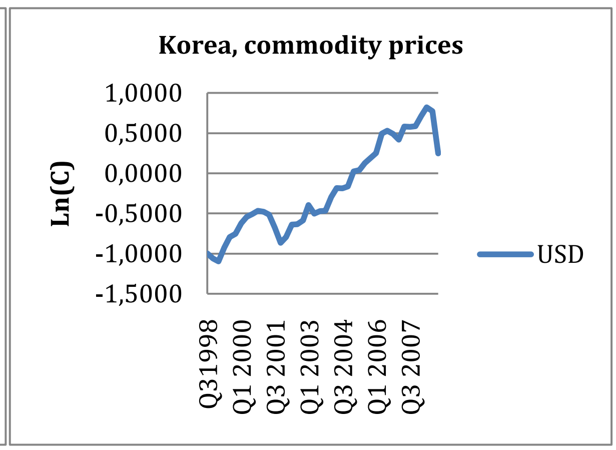


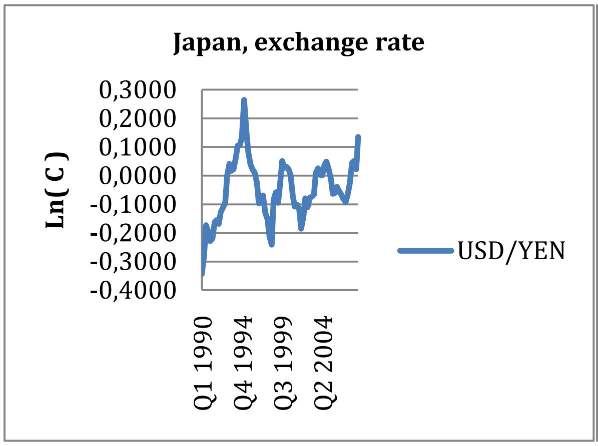


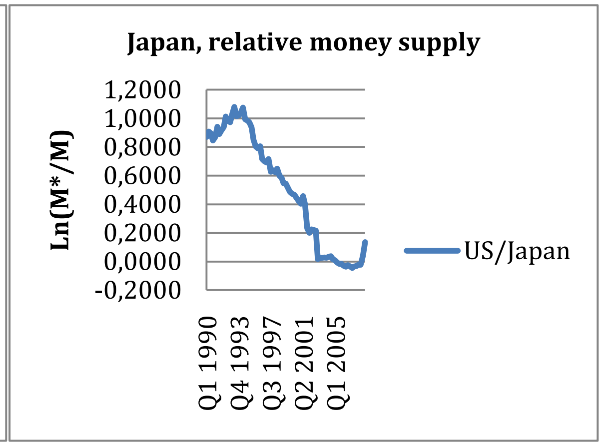


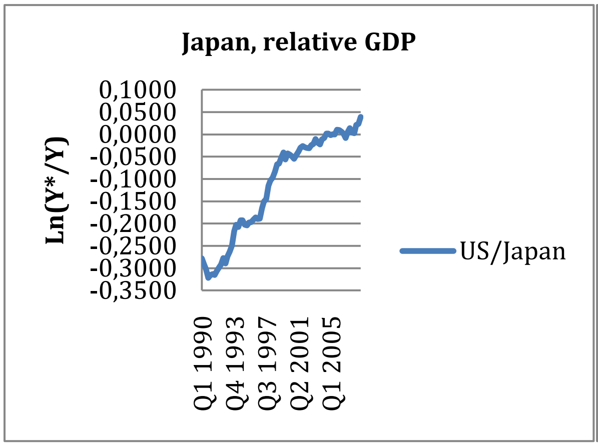


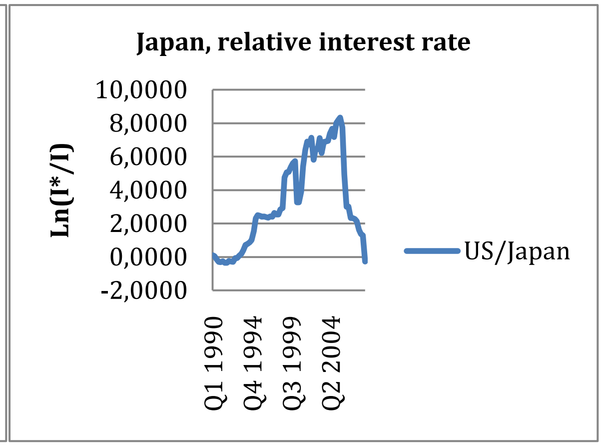


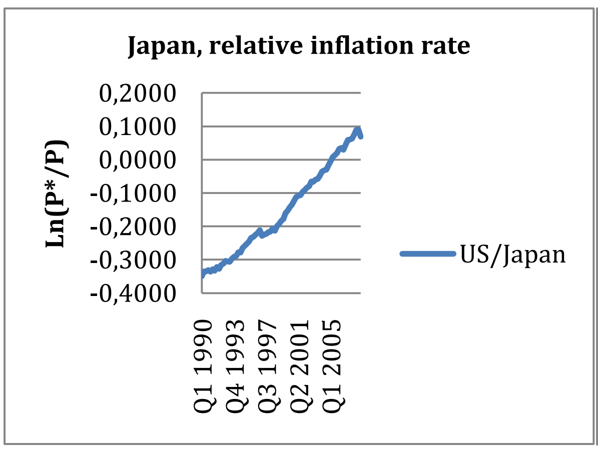


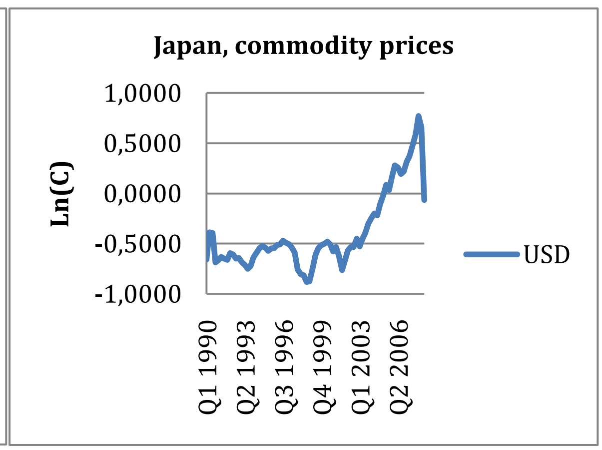

Japan, exchange rate
0,3000
0,2000
0,1000
0,0000
-0,1000
-0,2000
-0,3000
-0,4000
Ln(C)
Q1 1990
Q4 1994
Q3 1999
Q2 2004
USD/YEN


Japan, relative money supply
1,2000
1,0000
0,8000
0,6000
0,4000
0,2000
0,0000
-0,2000
Ln(M*/M)
Q1 1990
Q4 1993
Q3 1997
Q2 2001
Q1 2005
US/Japan


Japan, relative GDP
0,1000
0,0500
0,0000
-0,0500
-0,1000
-0,1500
-0,2000
-0,2500
-0,3000
-0,3500
Ln(Y*/Y)
Q1 1990
Q4 1993
Q3 1997
Q2 2001
Q1 2005
US/Japan


Japan, relative interest rate
10,0000
8,0000
6,0000
4,0000
2,0000
0,0000
-2,0000
Ln(I*/I)
Q1 1990
Q4 1994
Q3 1999
Q2 2004
US/Japan


Japan, relative inflation rate
0,2000
0,1000
0,0000
-0,1000
-0,2000
-0,3000
-0,4000
Ln(P*/P)
Q1 1990
Q4 1993
Q3 1997
Q2 2001
Q1 2005
US/Japan


Japan, commodity prices
1,0000
0,5000
0,0000
-0,5000
-1,0000
Ln(C)
Q1 1990
Q2 1993
Q3 1996
Q4 1999
Q1 2003
Q2 2006
USD

Appendix 4 – Unit root tests

DF test in level

	Korea			Japan		
variable	β	t_{obs}	H_0	β	t_{obs}	H_0
s	0,901	12,945	not rejected	0,886	16,059	not rejected
m	1,031	17,712	not rejected	0,908	20,24	not rejected
y	0,194	1,285	not rejected	0,936	24,722	not rejected
i	0,856	10,329	not rejected	0,968	33,037	not rejected
p	0,787	8,947	not rejected	0,885	19,945	not rejected
c	0,817	6,857	not rejected	0,889	17,148	not rejected

ADF in level

	Korea				Japan			
variable	β	t_{obs}	lags	H_0	β	t_{obs}	lags	H_0
s	0,886	13,979	1	not rejected	0,848	14,793	3	not rejected
m	1,011	13,939	3	not rejected	0,911	17,609	4	not rejected
y	0,633	4,204	4	not rejected	0,946	24,214	4	not rejected
i	0,688	7,862	3	not rejected	0,961	33,056	1	not rejected
p	0,693	6,618	4	not rejected	0,867	18,204	4	not rejected
c	0,774	6,327	1	not rejected	0,860	16,038	3	not rejected

DF in first differences

	Korea			Japan		
variable	β	t_{obs}	H_0	β	t_{obs}	H_0
Δs	0,459	3,228	not rejected	0,886	16,059	not rejected
Δm	0,068	0,413	not rejected	0,908	20,24	not rejected
Δy	-0,651	-5,284	rejected	0,936	24,722	not rejected

Δi	0,377	2,539	not rejected	0,968	33,037	not rejected
Δp	-0,087	-0,541	not rejected	0,885	19,945	not rejected
Δc	0,187	1,172	not rejected	0,889	17,148	not rejected

ADF in first differences

	Korea				Japan			
variable	β	t_{obs}	lags	H_0	β	t_{obs}	lags	H_0
Δs	0,462	2,664	1	not rejected	0,238	1,234	2	not rejected
Δm	0,424	1,488	3	not rejected	0,402	1,602	3	not rejected
Δy	-	-	-	-	0,384	2,277	2	not rejected
Δi	0,635	3,697	2	not rejected	0,297	2,050	1	not rejected
Δp	0,267	0,806	3	not rejected	-0,088	-0,469	1	not rejected
Δc	-0,032	-0,15	1	not rejected	-0,059	-0,310	4	not rejected

DF in second differences

	Korea			Japan		
variable	β	t_{obs}	H_0	β	t_{obs}	H_0
Δ^2s	-0,158	-0,989	not rejected	-0,270	-2,375	rejected
Δ^2m	-0,457	-3,137	rejected	-0,416	-3,881	rejected
Δ^2y	-	-	-	-0,467	-4,480	rejected
Δ^2i	-0,322	-2,094	rejected	-0,405	-3,762	rejected
Δ^2p	-0,541	-3,698	rejected	-0,580	-6,043	rejected
Δ^2c	-0,169	-1,056	not rejected	-0,067	-0,569	not rejected

ADF in second differences

	Korea				Japan			
variable	β	t_{obs}	lags	H_0	β	t_{obs}	lags	H_0
$\Delta^2 s$	-0,369	-1,499	1	not rejected	-	-	-	-
$\Delta^2 m$	-	-	-	-	-	-	-	-
$\Delta^2 y$	-	-	-	-	-	-	-	-
$\Delta^2 i$	-	-	-	-	-	-	-	-
$\Delta^2 p$	-	-	-	-	-	-	-	-
$\Delta^2 c$	-0,594	-2,179	1	rejected	-0,495	-2,600	1	rejected

DF in third differences

	Korea			Japan		
variable	β	t_{obs}	H_0	β	t_{obs}	H_0
$\Delta^3 s$	-0,401	-2,661	rejected	-	-	-
$\Delta^3 m$	-	-	-	-	-	-
$\Delta^3 y$	-	-	-	-	-	-
$\Delta^3 i$	-	-	-	-	-	-
$\Delta^3 p$	-	-	-	-	-	-
$\Delta^3 c$	-	-	-	-	-	-

Critical τ-values at the 5% level

	Korea	Japan
estimated n	50	100
no intercept, no trend	-1,95	-1,95
intercept, no trend	-2,93	-2,89
intercept and trend	-3,5	-3,45

Appendix 5 – Co-integration tests

Korea

model	adj R^2	d_{obs}	d_{crit}	H_0	EG β_1	t_{obs}	T_{crit}	H_0
FLMA	0,316	2,914	0,386	rejected	-0,861	-10,155	-3,7429	rejected
FLMA(c)	0,319	2,785	0,386	rejected	-0,849	-9,633	-4,1000	rejected
SPMA	0,297	2,929	0,386	rejected	-0,863	-10,249	-4,1000	rejected
SPMA(c)	0,306	2,809	0,386	rejected	-0,853	-9,815	-4,1418	rejected

Japan

model	adj R^2	d_{obs}	d_{crit}	H_0	EG β_1	t_{obs}	T_{crit}	H_0
FLMA	0,065	2,439	0,386	rejected	-0,798	-11,169	-3,7429	rejected
FLMA(c)	0,061	2,431	0,386	rejected	-0,800	-11,227	-4,1000	rejected
SPMA	0,137	2,331	0,386	rejected	-0,793	-10,983	-4,1000	rejected
SPMA(c)	0,125	2,338	0,386	rejected	-0,794	-10,988	-4,1418	rejected

Appendix 6 – Model summary

Korea

model	adj R^2	m	y	i	p	c	co-int
FLMA	0,316	0,166	-0,01	0,626***	-	-	yes
FLMA(c)	0,319	0,208	-0,043	0,571***	-	0,168	yes
SPMA	0,297	0,166	-0,018	0,635***	-0,026	-	yes
SPMA(c)	0,306	0,214	-0,076	0,591***	-0,091	0,202	yes

Japan

model	adj R^2	m	y	i	p	c	co-int
FLMA	0,065	0,199*	0,152	-0,163	-	-	yes
FLMA(c)	0,061	0,2*	0,159	-0,163	-	-0,093	yes
SPMA	0,137	0,269**	0,082	-0,186*	-0,300**	-	yes
SPMA(c)	0,125	0,272**	0,076	-0,187*	-0,314**	0,032	yes

implies significance at the 10% level

** implies significance at the 5% level

*** implies significance at the 1% level

Appendix 7 – Co-integration tests for s and c

country	adj R^2	d_{obs}	d_{crit}	H_0	EG β_1	t_{obs}	T_{crit}	H_0
Korea	0,089	2,315	0,386	rejected	-0,811	-8,436	-1,9393	rejected
Japan	-0,008	2,412	0,386	rejected	-0,797	-11,128	-1,9393	rejected

Appendix 8 – Granger Causality Test

Korea

expl var	k	F_{obs}	F_{crit}	H_0	d	t_{obs}	t_{crit}	H_0
Δ^3c	1	9,05036	8,5988	rejected	-1,072	6,754***	3,307	rejected
Δ^4s	1	4,567164	8,5988	not rejected	0,219	0,936	-	not rejected
Δ^3c	2	4,216912	4,4747	not rejected	-1,278	4,267***	3,307	rejected
Δ^4s	2	1,556624	4,4745	not rejected	0,359	0,918	-	not rejected
Δ^3c	3	3,111111	3,3557	not rejected	-1,608	3,588***	3,307	rejected
Δ^4s	3	0,826568	3,3557	not rejected	0,539	0,893	-	not rejected

Δ^3c	4	2,002427	2,846	not rejected	-1,463	2,331**	2,704	not rejected
Δ^4s	4	0,990533	2,846	not rejected	1,221	1,463	-	not rejected

Japan

expl var	k	F_{obs}	F_{crit}	H_0	d	t_{obs}	t_{crit}	H_0
Δ^3c	1	0	8,5645	not rejected	-1,259	12,125***	3,232	rejected
Δ^3s	1	5,762105	8,5645	not rejected	-0,003	0,014	-	not rejected
Δ^3c	2	2,828571	4,4212	not rejected	-1,391	7,515***	3,232	rejected
Δ^3s	2	0,283397	4,4212	not rejected	-0,112	0,368	-	not rejected
Δ^3c	3	2,163636	3,2939	not rejected	-1,727	6,983***	3,232	rejected
Δ^3s	3	1,054907	3,2939	not rejected	0,033	0,08	-	not rejected
Δ^3c	4	1,909091	2,777	not rejected	-1,727	5,094***	3,232	rejected
Δ^3s	4	1,09027	2,777	not rejected	-0,472	0,797	-	not rejected

implies significance at the 10% level

** implies significance at the 5% level

*** implies significance at the 1% level

If the t_{obs} is of higher significance than 10% we have not included t_{crit} and hence not rejected the hypothesis.

$$F_{obs} = \frac{\frac{RSS_R - RSS_{UR}}{m}}{\frac{RSS_{UR}}{n-k}}$$