

## A Note on the Real Currency Exchange Rate: Definitions and Implications

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### Abstract

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The real exchange rate (RER) in the literature is defined as the relative national price levels between two economies with the corresponding nominal exchange rate being an auxiliary to convert the unit of account such that two price levels are measured in a single currency. Its subject is not the currency or exchange rate, but the relative cost of living between two economies. This note proposes to define the real exchange rate of a currency as the nominal exchange rate adjusted for relative purchase power. It measures how much the currency can purchase in real terms, or the purchase power of the currency abroad relative to that at home. In this definition, the subject is the currency which serves as medium of exchange. It implies that its measure should be asymmetric; the price at home is broad like CPI, but the price abroad is only for imports. It is hypothesized that the RER with this medium-of-exchange feature is expected to be more relevant to exchange and hence the trade balance.

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**Keywords:** Real exchange rate, currency, medium of exchange, unit of account, trade balance

### 1. Introduction

Nominal exchange rate is defined as the price of a *currency* in terms of another currency. In parallel, real currency exchange rate should be defined as the price of the currency in real terms. In the literature and textbooks, however, it is defined as the relative price levels between two countries, rather than how much the currency can purchase in real terms.

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Some authors may have noted this issue and attempted to define it for currency. Nevertheless, they still end up with the price ratio of the goods between two countries, rather than the exchange rate of currencies. This paper attempts to provide a formal and natural definition for the real *currency* exchange rate, and to discuss some of its implications in international macroeconomics.

The subject in the term "*currency* exchange rate," nominal or real, should be a currency, and a real variable is converted from its corresponding nominal counterpart after adjusted for purchasing power. Based on these two principles of economics, we propose to define real *currency* exchange rate as the nominal exchange rate adjusted for the *relative* purchasing power. It can also be interpreted as the purchasing power of the currency abroad relative to that at home. In this treatment, the currency is the subject of the exchange rate and it serves as *medium of exchange* at home as well as abroad. In the conventional definition for the real exchange rate, in contrast, the subject is the relative national prices and the currency only plays a role of *unit of account* as the nominal exchange rate merely helps convert different price levels into a common currency. Conceptually, these two treatments are different in the starting point: our definition starts with the nominal exchange rate and hence the subject is currency and exchange, whereas the conventional treatment starts with the ratio of national price levels and hence the subject is the relative cost of living.

The difference in the starting point between the two approaches implies that these two kinds of real exchange rates should be measured differently as well, because the currency plays different roles in the two treatments. In our proposal the currency functions as medium of exchange, whereas in the conventional treatment it serves as unit of account. Therefore, in the real *currency* exchange rate as we propose here, the baskets behind the price levels comprise those goods exclusively that the *home* currency would normally purchase. More specifically, while the home basket contains (almost) all goods – tradable and non-tradable, the foreign basket should primarily involve traded goods (i.e., imports) from the perspective of residents at home. In the conventional treatment, on the other hand, the real exchange rate (of goods) essentially measures the relative national price levels between the two countries. Consequently, both home and foreign baskets are measured by broad indexes such as CPI. When the baskets behind the two kinds of real exchange rate differ, their measures should be somehow different as well.

The asymmetric measurement for our proposed real currency exchange rate has interesting implications in some relevant topics on the open-economy macroeconomics.

For example, in one-country, open-economy macroeconomic models real exchange rate is usually defined as the relative price of tradable goods to non-tradable goods (e.g., Végh, 2013, p.151). We show that under our definition the real currency exchange rate is a power function of the relative price of tradable goods to non-tradable goods; in particular, the former equals to the latter when the home goods are all non-tradable. Another implication of our medium-of-exchange based RER is that the real *currency* exchange rate is more relevant to exchange and hence the trade balance than the conventional treatment.

The remaining paper is organized as follows. Section 2 addresses some problems in the conventional treatment on the real exchange rate as the motivation for this study. In section 3, we propose our definition for the real *currency* exchange rate, followed by the discussion of the difference between the two kinds of treatments on the real exchange rates in section 4. Section 5 provides some examples for the implications of the real currency exchange rate as proposed in this paper.

## 2. Some Problems in the Conventional Treatment on the Real Exchange Rate

We start with the conventional treatment of the “real exchange rate” in the literature. Denote  $E_{\text{€}/\$}$  the nominal exchange rate of a dollar in terms of euro, and  $P_{\text{EU}}$  and  $P_{\text{US}}$  the price levels in Europe and in the U.S., respectively. Then, the real exchange rate between the two economies is formally defined and computed as follows:

$$q_{\text{EU}/\text{US}} = \frac{E_{\text{€}/\$} P_{\text{US}}}{P_{\text{EU}}} . \quad (1)$$

Here, the numerator in  $q_{\text{EU}/\text{US}}$  is the price level of the U.S. goods, and the denominator is that of the European goods, both denominated in euro with  $E_{\text{€}/\$}$  being an auxiliary to convert different currencies into a single one. Clearly,  $q_{\text{EU}/\text{US}}$  measures the relative price level of the U.S. goods to European goods, i.e., the ratio of the cost of living between the two economies. If  $q_{\text{EU}/\text{US}} > (<) 1$ , it is said that the U.S. goods are more (less) expensive than the European goods, and in particular, if  $q_{\text{EU}/\text{US}} = 1$ , the goods between the two economies are equally priced. That is, the Law Of One Price (LOOP) holds in

macro version, though almost all authors refer to it as the “Purchasing Power Parity” (PPP).<sup>3</sup> Also, when  $q_{EU/US}$  increases (decreases), it is said that the U.S. goods experience real appreciation (depreciation). In this treatment, it is all about the U.S. goods and has nothing to do with the U.S. dollars.

A standard interpretation for  $q_{EU/US}$  is that it is the rate at which the goods between the two countries are traded.<sup>4</sup> Unfortunately, this interpretation is irrelevant and problematic. For example, if  $q_{EU/US} = 1/2$ , it would imply that two baskets of the U.S. goods are traded for one basket of European goods in the world market. This interpretation may make sense if the two baskets comprise quite differentiated tradable goods. But what if the goods in the two baskets are very close substitutes? What if the goods are primarily non-tradable? In either case, so-called “exchanges” can only be “hypothetical.”<sup>5</sup> Institutionally and theoretically, a more relevant, and perhaps the correct, interpretation for  $q_{EU/US} = 1/2$  should be that the goods in Europe are twice as expensive as those in the U.S. That is, this so-called “real exchange rate” is more relevant to the comparison of cost of living than to the exchange or trade between the two economies.

The root source for the problem behind such conventional treatment is that the subject in the real exchange rate (of goods) is not the currency, but the ratio of national price levels. That is, in expression  $\frac{E_{\$/\text{€}} P_{US}}{P_{EU}}$ , its starting point is ratio  $\frac{P_{US}}{P_{EU}}$ , but not  $E_{\$/\text{€}}$ ; the latter only helps convert the numerator and denominator of the former into a single currency as an auxiliary, rather than the subject in this term. In other words, the currency through the nominal exchange rate in this conventional treatment does not play a role of *medium of exchange*, but just serves as *unit of account*.

Nevertheless, the subject of the real *currency exchange rate* should be the currency. As Végh (2013, p.154) noted, “In monetary models, it is the currency that can appreciate or depreciate in either nominal or real terms.

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<sup>3</sup>Literally speaking, “Purchasing Power Parity” (PPP) means that the purchase power of a currency is the same, while “Law of One Price” (LOOP) means that the same goods are sold at the same price everywhere. Note that  $q_{EU/US}$  is not defined for currency but for goods. When  $q_{EU/US} = 1$ , it simply means that the prices of the goods between the two economies are equal. Hence, it is more relevant to claim LOOP instead of PPP in this case.

<sup>4</sup> See, for example, Mankiw (2013, p. 150), Williamson (2014, p. 569), Ball (2012, p. 163), Krugman and Obstfeld (2009, p. 401), Feenstra and Taylor (2012, p. 67), among others.

<sup>5</sup> See Krugman and Obstfeld (2009, p. 403).

The expressions ‘real appreciation’ and ‘real depreciation’ thus refer to an appreciation or depreciation of the currency in real terms.”

We cannot agree with Végh more in this regard. In fact, some other authors also havenoted that  $E_{\text{€}/\$}$ , instead of  $\frac{P_{\text{US}}}{P_{\text{EU}}}$ , should be the starting point (i.e., the subject) when defining the real exchange rate. For example, Carbaugh (2009, p. 377) defines that “the real exchange rate is the nominal exchange rate adjusted for relative price levels,” and Jones (2014, p. 545) states that “[I]t is computed by adjusting the nominal exchange rate for the relative price level at home and abroad.” Formally, they write the real exchange rate as

$$q_{\text{€}/\$} = E_{\text{€}/\$} \frac{P_{\text{US}}}{P_{\text{EU}}} \quad (2)$$

Indeed, they obviously mean to regard the currency as the subject when defining the “real exchange rate”, which is adjusted from the corresponding nominal exchange rate- the starting point. In their terminology, the “relative price level” that adjusts the nominal exchange rate evidently refersto  $\frac{P_{\text{US}}}{P_{\text{EU}}}$ . This ratio itself, however, is not the “relative price level” at all but completely meaningless, because  $P_{\text{US}}$  and  $P_{\text{ER}}$  are denominated in different currencies. Rather, the “relative price level” is exactly  $q_{\text{EU}/\text{US}} = \frac{E_{\text{€}/\$} P_{\text{US}}}{P_{\text{EU}}}$  *per se*. Thus, on one hand, they verbally refer to the “real exchange rate” as the “nominal exchange rate adjusted for the relative price levels;” on the other hand, they formally define the real exchange rate as “the relative price levels” itself as measured in terms of a single currency. Therefore, their definition for the real *currency* exchange rate is internally inconsistent, though they mean to treat the currency as the subject by starting with the nominal exchange rate.

Then, how should the real *currency* exchange rate be defined?

### 3. The Real *Currency* Exchange Rate: A Proposed Definition

The subject in the *currency* exchange rate, nominal or real, should be a currency. In the literature the nominal exchange rate is defined as the price of a *currency* in terms of another currency. The subject in this definition for the nominal exchange rate is obviously the *currency*.

Institutionally, for example, the value of  $E_{\text{€}/\$}$  tells us how much euro a U.S. dollar can purchase in the foreign exchange market. In parallel, the real exchange rate of the U.S. dollar should tell us how much a U.S. dollar would purchase in real terms.

In macroeconomics, a nominal variable is converted to its corresponding real variable when adjusted for purchasing power. Hence, the real exchange rate of, say, a U.S. dollar to euro, denoted  $q_{\text{€}/\$}$ , should be obtained from  $E_{\text{€}/\$}$  by adjusting for purchasing power. Note that  $E_{\text{€}/\$}$  itself is a ratio between a euro and a dollar. Hence, it should be adjusted for the relative purchasing power between the two currencies. According to these principles, we propose to define the real exchange rate (of the U.S. dollar to euro) as the corresponding nominal exchange adjusted for *relative purchasing power*.<sup>6</sup> Formally, it is written as follows:

$$q_{\text{€}/\$} = E_{\text{€}/\$} \frac{\frac{1}{P_{\text{EU}}}}{\frac{1}{P_{\text{US}}}}, \quad (3)$$

where  $1/P_{\text{EU}}$  and  $1/P_{\text{US}}$  are the purchasing power of a euro and a dollar, respectively, measured by some basket in that economy. Note that mathematically, we have

$$\frac{\frac{1}{P_{\text{EU}}}}{\frac{1}{P_{\text{US}}}} = \frac{P_{\text{US}}}{P_{\text{EU}}}. \quad (4)$$

So, one would ask what the difference between (2) and (3) is? Though the two sides of equation (4) are mathematically equal, in economics its LHS is meaningful and RHS is meaningless. This is because  $1/P_{\text{EU}}$  and  $1/P_{\text{US}}$  represent the purchase power of a euro and a dollar, respectively, measured in real terms. Consequently, the LHS gives the relative purchase power. On the other hand,  $P_{\text{EU}}$  and  $P_{\text{US}}$  are price levels denominated in different currencies, and hence their ratio is meaningless.

Re-writing (3) as

$$q_{\text{€}/\$} = \frac{E_{\text{€}/\$} \frac{1}{P_{\text{EU}}}}{\frac{1}{P_{\text{US}}}}, \quad (5)$$

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<sup>6</sup> We use the U.S. dollar and euro as an example for the convenience of presentation. In general, it can be the currencies of the "Home" country (H, to replace \$) and the "Foreign" country (F, to replace €).

we can also interpret the real exchange rate (of dollar) as the purchasing power of a dollar abroad relative to that at home. Specifically,  $q_{\text{€}/\$} > 1$  implies that a dollar has more purchasing power abroad than at home, whereas  $q_{\text{€}/\$} < 1$  indicates that a dollar has more purchasing power at home than abroad. When  $q_{\text{€}/\$} = 1$ , in particular, the purchasing power of a dollar is equal everywhere, making "Purchasing Power Parity" a proper term. Accordingly, as  $q_{\text{€}/\$}$  increases, we say that the U.S. dollar appreciates in real terms, whereas  $q_{\text{€}/\$}$  decreases, the U.S. dollar experiences real depreciation. Note that the subject in (3) and (5) is the currency (i.e., the U.S. dollar, in this example) and it serves as *medium of exchange*, because it regards the how much (of what) a dollar would purchase in real terms.

Harberger (2004) offers another step-by-step approach to defining the "real-currency exchange rate" that yields the same outcome as ours. It starts from the nominal exchange rate to the real exchange rate as follow:

$E_{\text{€}/\$}$  = the nominal euro price of the nominal dollar;

$\frac{E_{\text{€}/\$}}{P_{\text{EU}}}$  = the real euro price of the nominal dollar;

$q_{\text{€}/\$} = \left( \frac{P_{\text{EU}}}{1} \right) \frac{E_{\text{€}/\$} P_{\text{US}}}{P_{\text{EU}}} =$  the real euro price of the real dollar.<sup>7</sup>

This method is also natural and logical. The difference between Harberger's and ours is that he actually deals with "real-currency exchange rate," whereas we discuss "real currency exchange rate," though the two approaches end up with the same expression as well as consistent interpretations.

#### 4. Differences between $q_{\text{€}/\$}$ and $q_{\text{EU}/\text{US}}$

Our proposed real exchange rate of the U.S. dollar to euro,  $q_{\text{€}/\$}$ , measures how much a dollar can purchase abroad relative to that at home in real terms. It implies that the U.S. dollar serves as *medium of exchange* at home as well as abroad via exchange to the foreign currency as indicated by  $E_{\text{€}/\$}$ .

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<sup>7</sup> We add the item within the parenthesis, since it exactly interprets "the real euro price of the real dollar."

Hence, the subject in this real *currency* exchange rate is the currency in deed as well as in name. In contrast,  $q_{EU/US}$ , which should be referred to as the exchange rate *of goods*, essentially measures the relative national price levels between the two economies. Though currencies are involved as indicated by the nominal exchange rates, they do not function as medium of exchange, but *unit of account* that merely helps convert the price levels between two economies into a common currency. The subject in this conventional definition is not the currency, but the ratio of national price levels between the two economies. It may somewhat explain why it is denoted  $q_{EU/US}$  in many textbooks instead of  $q_{\$/\$}$ .<sup>8</sup>

Such a difference in the functions of the currency between  $q_{EU/US}$  and  $q_{\$/\$}$  implies that they should be measured differently as well. Given the same price levels  $P_{US}$  and  $P_{EU}$  and the nominal exchange rate  $E_{\$/\$}$ , indeed,  $q_{\$/\$}$  and  $q_{EU/US}$  equal to each other mathematically. However, the price level  $P_{EU}$  in  $q_{EU/US}$  and in  $q_{\$/\$}$  may not be the same. On one hand,  $P_{EU}$  in  $q_{EU/US}$  is a broad measure of price levels, such as CPI. On the other hand, the basket behind  $P_{EU}$  in  $q_{\$/\$}$  contains exclusively the imports to the U.S. from the Europe (from an American's perspective). This is because the currency (i.e., the U.S. dollar) serves as medium of exchange, and hence, it would only purchase the imports to the U.S. Formally,  $q_{\$/\$}$  should be re-written as follows:

$$q_{\$/\$} = \frac{\frac{E_{\$/\$}}{P_{EU}^T}}{\frac{1}{P_{US}}} = \frac{E_{\$/\$} P_{US}}{P_{EU}^T}, \quad (6)$$

where  $P_{EU}^T$  denotes the prices of tradable goods of Europe to U.S. Comparing  $q_{EU/US}$  in (1) with  $q_{\$/\$}$  in (6), we have the following

**Proposition 1:** Given  $E_{\$/\$}$  and  $P_{US}$ ,  $q_{EU/US} = q_{\$/\$}$ , if and only if,  $P_{EU} = P_{EU}^T$ .

Intuitively, the condition  $P_{EU} = P_{EU}^T$  means that all European goods are exportable (to the U.S.). It may not be necessarily true, in general. Therefore, the real currency exchange rate,  $q_{\$/\$}$ , as we propose in this note, is different from the conventional real exchange rate  $q_{EU/US}$ , in concept as well as in measuring.

<sup>8</sup> See, for example, Feenstra and Taylor (2012, p. 66-67). We also note that Krugman, *et al* (2015, p.132) actually have denoted the real exchange rate  $q_{\$/\$}$ , but still define and interpret it like  $q_{EU/US}$ .

The asymmetric measure in the “foreign” prices between  $q_{\text{€}/\$}$  and  $q_{\text{\$/€}}$  leads to the following

**Proposition 2:** If  $P_{\text{EU}} \neq P_{\text{EU}}^T$  or  $P_{\text{US}} \neq P_{\text{US}}^T$ , then  $q_{\text{€}/\$} \neq \frac{1}{q_{\text{\$/€}}}$ .

This is because the foreign price level in the expression only involves the tradable goods, whereas the home price level contains all goods from the home country perspective. But “home”-vs.-“foreign” is a relative concept. When the role switches, so do the baskets behind the price levels. The asymmetry of the price levels in the definition for  $q_{\text{€}/\$}$  leads to such an asymmetric property between  $q_{\text{€}/\$}$  and  $q_{\text{\$/€}}$ .

We summarize the key differences between  $q_{\text{EU/US}}$  and  $q_{\text{€}/\$}$  in Table 1.

Features	$q_{\text{EU/US}} = \frac{E_{\text{€}/\$} P_{\text{US}}}{P_{\text{EU}}}$	$q_{\text{€}/\$} = \frac{E_{\text{€}/\$} P_{\text{US}}}{P_{\text{EU}}^T}$
Interpretation	The ratio of national price levels;	The ratio of a currency’s purchasing power abroad
Subject or starting point	The subject is the price ratio;	The subject is a currency;
Meaning	The exchange rate of goods;	The exchange rate of currency;
The role of currency	Currency serves as unit of account;	Currency serves as medium of exchange;
Measure	$P_{\text{EU}}$ is the CPI of Europe;	$P_{\text{EU}}^T$ is the price of imports from Europe.
Symmetry/asymmetry	$q_{\text{EU/US}} = 1/q_{\text{US/EU}}$	$q_{\text{€}/\$} \neq 1/q_{\text{\$/€}}$ , unless $P_{\text{EU}} = P_{\text{EU}}^T$ and $P_{\text{US}} = P_{\text{US}}^T$

**Table 1. Summary of Differences Between  $q_{\text{EU/US}}$  and  $q_{\text{€}/\$}$**

### 5. Implications of Proposed real *Currency Exchange Rate*

The proposed definition of  $q_{\text{€}/\$}$  has some implications to some relevant topics in international macroeconomics. We provide a couple of examples as follows.

**Example 1.** *The connection between two prevailing definitions for real exchange rate.*

In one-country, open-economy macroeconomics, it also usually defines the real exchange rate as the relative price of non-tradable goods in terms of tradable goods (or its inverse), where no exchange is explicitly involved as there is only one country, open economy though, in the model.<sup>9</sup> This definition is evidently different from the conventional real exchange rate of goods, where two countries are explicitly specified.

<sup>9</sup> See, for example, Végh (2013, p.151), Uribe (2003) and Chinn (2006).

Though the difference is recognized, no clear connection between the two methods is addressed, yet, to the best of our knowledge. Our definition for the real currency exchange rate, also based on two-country framework, is somehow consistent to this “tradable over non-tradable” treatment, and we discuss this point below.

Formally, let  $P$  be the home price level that is the geometric average of the prices of non-tradable goods and tradable goods, i.e.,  $P = P_N^\alpha P_T^{1-\alpha}$ , where  $N$  stands for non-tradable and  $T$  for tradable, and  $\alpha$  is the share of non-tradable goods. Also, let  $P_T^*$  be the foreign prices of tradable goods. Under our definition for the real currency exchange rate, we have

$$q_{F/H} = \frac{\frac{E_{F/H}}{P_T^*}}{\frac{1}{P}} = \frac{E_{F/H} P_N^\alpha P_T^{1-\alpha}}{P_T^*} = \frac{P_N^\alpha P_T^{1-\alpha}}{P_T^*} = \left(\frac{P_N}{P_T}\right)^\alpha \quad (7)$$

It shows that the real currency exchange rate, under our definition, is a power function of the relative price of non-tradable goods in terms of tradable goods at home. Note that in (7), if  $\alpha = 1$ , i.e., if the home goods are all non-tradable, then we have

$$q_{F/H} = \frac{P_N}{P_T} \quad (8)$$

Hence, in this extreme case, the real exchange rate under our definition equals to the relative price of non-tradable goods in terms of tradable goods, as usually claimed in the literature of open-economy macroeconomics with one-country models. On the other hand, if  $\alpha = 0$ , i.e., if all home goods are tradable, then it implies from (7) that  $q_{F/H} = 1$ , i.e., PPP holds.<sup>10</sup> It is worth noting that  $P_T^*$ , instead of  $P^*$ , in the expression for  $q_{F/H}$  plays a crucial role to obtain (7) and (8). Therefore, our proposed definition for the real exchange rate, though based on two-country models, is also consistent with the definition for the real exchange rate in terms of tradable vs. non-tradable prices primarily for one-country models of open-economy macroeconomics.

### **Example 2.** *How does real exchange rate affect import and export?*

<sup>10</sup> We can easily show that the real exchange rate is also an increasing function of  $P_N/P_T$  if the price level is a weighted arithmetic average of the prices of non-tradable goods and tradable goods. The features of extreme cases also hold when the home goods are exclusively non-tradable or tradable.

In our proposed treatment of real exchange rate, its effects on exports and imports are *asymmetric*, because  $q_{F/H} \neq 1/q_{H/F}$ , where the subscripts H and F stand for Home and Foreign countries, respectively. Therefore, we have

$$\begin{aligned} TB(q_{F/H}, q_{H/F}) &= EX(q_{H/F}) - IM(q_{F/H}) \\ &= EX\left(\frac{E_{H/F}P_F}{P_H^T}\right) - IM\left(\frac{E_{F/H}P_H}{P_F^T}\right), \quad EX' > 0, \text{ and } IM' > 0. \end{aligned}$$

The issue of interest is how such asymmetry between  $q_{H/F}$  and  $q_{F/H}$  affects the trade balance, in particular, when it is very imbalanced for some open economies. It is an empirical question by nature and it is beyond the scope of this short note. We plan to work on this topic in a separate paper, and we sketch the plan here. In the conventional treatment of real exchange rate, it suggests that the trade balance should increase with the real exchange rate under the Marshall-Lerner condition. However, the data and empirical researches do not support it consistently (e.g., see Bahmani-Oskooee and Niroomand, 1998, and the references provided there). Our conjecture is that if using the approach as proposed in this note, the trade balance is expected to be “more smoothly” related to the “real currency exchange rate” as we propose. It is because our definition for the real exchange rate is more relevant to “exchange” than “conversion”. We hypothesize that under our proposed definition for the real exchange rate the modified Marshall-Lerner condition could be more relaxed than its original version. Of course, this hypothesis is subject to test.

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