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Money Stock versus Monetary Base in Time-Frequency Exchange Rate Determination

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Abstract

In this study, we provide empirical evidence of the changing role of the money supply in the determination of the Japanese yen/U.S. dollar exchange rate, using time–frequency analysis. We demonstrate that in the short-run, money supply has a stable significant effect on the exchange rate only after the introduction of quantitative easing policies, together with a remarkable difference between the money stock and the monetary base. Under quantitative easing policies, while money stock has a limited role, at best, in short-run exchange rate dynamics, increases in the monetary base cause the currency to depreciate in the short-run. The notable role of the monetary base remains exceptionally stable over time only in quantitative easing regimes, while the exchange rate is unstably connected to other fundamentals. Moreover, in the long-run, the monetary base outperforms the money stock in explaining the exchange rate, in general.

Keywords: Exchange rate; Money stock; Monetary base; Quantitative easing; Time–frequency analysis

JEL classification: C49; E58; F31

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1 Introduction

While economists have long presumed that the relative money supply between two countries might play an important role in accounting for bilateral exchange rate dynamics, it seems that the global financial crisis and Great Recession in the late 2000s reignited academic interest in the role of the money supply in exchange rate determination. As is well known, in addition to the Bank of Japan, which initially introduced unconventional monetary policy in the 2000s, central banks, such as the Federal Reserve Bank and the European Central Bank, began to conduct unconventional monetary policy after the recent macroeconomic crises. Before the introduction of these unconventional monetary policies, such as quantitative easing, money stock tended to comove with the monetary base in many industrialized countries (e.g., Euro Area, Japan, the United Kingdom, and the United States). However, massive monetary injections through quantitative easing have broken this stable relationship, thereby creating a large difference in the comovement of the money stock and the monetary base.

It is possible that quantitative easing policies have driven traders in the currency market to pay more attention to the monetary base than before. While the main instrument of traditional monetary policies is short-term interest rates, which are no longer a policy indicator under the zero lower bound, the monetary base rather than the money stock is a direct indicator reflecting the policy stance under quantitative easing periods. If traders are concerned about monetary fundamentals, we would expect that the introduction of quantitative easing policies would raise the traders' awareness regarding the monetary base. Thus, the recent introduction of quantitative easing policies provokes new questions: Do sharp increases in the monetary base cause currencies to depreciate even without increases in the money stock? Or, is the money stock more relevant to exchange rate dynamics than the monetary base, even under quantitative easing periods?

To answer these questions, we focus on the Japanese yen/U.S. dollar exchange rate in this study. This is because Japan embarked on a quantitative easing policy before the rest of the world in the period March 2001 to March 2006, and the data are available for a longer time period than in other countries. Moreover, as plotted in Figure 1, the timing of recent unconventional monetary policies following the global financial crisis differs between Japan and the United States. The Fed launched large-scale asset purchases (LSAP) immediately following the financial crisis and started tapering these off in January 2014; whereas the Bank of Japan finally introduced quantitative and qualitative monetary easing policies (the Abenomics monetary policy) in April 2013. In other words, the timing of the launch of the Abenomics monetary policy lags behind the Fed's LSAP by more than four years. Thus, such a timing difference allows us to capture relative changes in the monetary base and to identify the effect of a massive increase in the monetary base on the exchange rate.

[Insert Figure 1 around here]

Importantly, as can be seen in Figure 1, there is a striking difference between the money stock and monetary base after the 2000s. More specifically, the dominant behavior of the monetary base in both countries appears to change from low frequency (long-run) to high frequency (short-run) after quantitative easing policies are introduced. To the extent that quantitative easing policy is conducted to counteract recession, the business cycle frequency is likely to be more important under the quantitative easing policy than before. In contrast, the dominant behavior of the money stock appears to remain at low frequencies (long-run), even after quantitative easing policies are introduced. As depicted in the lower panels of Figure 1, money multipliers indicate directly the breaks in the stable short-run nexus between the two monetary aggregates.

In this study, motivated by such complicated breaks that occur not only over time but also across frequencies, we utilize a time–frequency analysis to investigate the monetary approach to the exchange rate (hereafter, MAER) determination. The time–frequency analysis provides us with time-varying and frequency-dependent relationships between the exchange rate and money supply. From an econometric viewpoint, our approach differs from extant literature that suffers from a common limitation. That is, the analytical frameworks in previous studies enable only a partial examination of time and frequency aspects.[1] To overcome such a limitation, the present study uses a time–frequency analysis to investigate both aspects simultaneously.

Our main findings are summarized as follows. Overall, we find a weak and unstable nexus between the Japanese yen/U.S. dollar exchange rate and monetary fundamentals, which is consistent with the predominant view of exchange rate dynamics (known as the exchange rate disconnect puzzle).[2] However, our results have a distinctly nonstandard flavor: money supply has a stable, significant effect on the exchange rate after the introduction of quantitative easing policies. Specifically, while relative money stock is shown to have a limited role, at best, in short-run exchange rate fluctuation, the relative monetary base (the Soros chart) is shown to play an important role in the short-run after quantitative easing policies are introduced. Importantly, such a significant role for the monetary base remains exceptionally stable throughout the quantitative easing regimes. These findings indicate that massive injections in the monetary base cause currencies to

[1] For example, while time-varying cointegration models can capture structural changes over time (e.g., Koop *et al.*, 2011), they analyze only the long-run and do not investigate the frequency at which the structural changes occur.

[2] See, e.g., Sarno (2005) for the exchange rate disconnect puzzle.

depreciate even without increases in money stock, implying that quantitative easing policies dramatically enhance the role of the monetary base in the short-run exchange rate determination. Moreover, in the long-run, the monetary base can explain the exchange rate, whereas the money stock fails to do so.

This study contributes to existing literature on the relationship between money supply and exchange rates in the following respects. First, in contrast to previous literature, we show that unconventional monetary policies result in profound structural changes in the short-run relationship. It is noteworthy that the structural changes occur in the short-run, although almost previous studies disregard the short-run relationship in the literature on the MAER. Second, we provide formal evidence of the Soros chart, which is well-known in the business world but has been rarely investigated in the academic literature.[3] To this end, while previous studies use money stock to test the MAER, our analysis is the first to consider the monetary base and to explore the difference between money stock and the monetary base in an MAER framework. Our evidence of the Soros chart could shed new light on the role of the monetary base in out-of-sample forecasts of exchange rates, although since the pioneering work by Meese and Rogoff (1983), it is widely recognized that monetary models are difficult to outperform a simple random walk model.

1.1 Related literature

This study relates to several strands of literature. First, the study builds on an empirical framework of the MAER literature, which is explained in subsequent sections. After entering the post-Bretton Woods floating rate era, the MAER determination has triggered a substantial number of studies starting with Frenkel (1976) and Bilson (1978). Most of the literature supposes that the monetary exchange rate model holds in the long-run and, accordingly, cointegration analysis is conducted by focusing on empirical modeling after the 1990s. These include, among many others, Groen (2000, 2002) and Rapach and Wohar (2002, 2004).

Incidentally, while almost all the MAER literature focuses only on the long-run relationship between exchange rates and monetary fundamentals, one important exception is Loría *et al.* (2010), who examine their short-run relationship as well. The authors employ a cointegrated structural vector autoregression model to investigate the determination of the Mexican peso/U.S. dollar exchange rate; as a result, they find that M2 money stock is related to the exchange rate in the short-run as well as the long-run, meaning that the model can be validated across various frequencies. Although the research issues in Loría *et al.* (2010) overlap with ours in the sense that both the short- and long-run are included

[3]In the Soros chart, the nominal exchange rate is traced through the relative monetary base. For example, Dekle and Hamada (2015) and Kano and Morita (2015) mention that the Soros chart is "a folk tale in the financial world" and "anecdotal evidence."

in the analyses, unlike their focus, our central concern is the short-run behavior of the monetary base under quantitative easing. Whether quantitative easing policy influences the exchange rate in the short-run is an important issue for monetary policy at the zero lower bound.

Second, it is closely related to another strand of growing literature that stresses the temporal instability of relationships between the exchange rate and fundamentals. For example, based on a parsimonious set of fundamentals, Park and Park (2013) demonstrate that the long-run relationship between the exchange rate and monetary fundamentals evolves over time by utilizing a time-varying cointegration model.[4] Moreover, using a broader set of macroeconomic fundamentals, including trade balance and net foreign assets, Sarno and Valente (2009) underscore frequent changes in fundamentals that can explain exchange rate movements. In this regard, from a survey of U.S. foreign exchange traders, Cheung and Chinn (2001) point out the time-changing role of individual macroeconomic fundamentals in exchange rate dynamics. In contrast to the temporal instability documented in this strand of the literature, we show that throughout quantitative easing regimes, the monetary base works stably as one of the most likely determinants of the exchange rate.

Finally, it also relates to the literature that investigates the so-called Soros chart describing the relationship between the relative monetary base between two countries and the bilateral exchange rate. Although the Soros chart is well-known in the business world, there are only a handful of academic papers, such as Hamada and Okada (2009), Dekle and Hamada (2015), and Miyao and Okimoto (2017), that adopt a different approach from the MAER and document the relationship between the monetary base and the exchange rate. While those studies provide evidence in favor of the Soros chart, this study is the first to show that the validity of the Soros chart depends on both time and frequency. That is, in the short-run, the Soros chart holds only after introducing quantitative easing policies, while in the long-run, it holds in general. It is, therefore, surprising that little attention has been directed towards assessing the effect of the monetary base on the exchange rate in the MAER framework.[5]

The rest of the paper is organized as follows. In Section 2, we explain our analytical framework and empirical strategy. In Section 3, we present the data and results. Section 4 concludes the paper.

[4]See also Basher and Westerlund (2009) who find that the monetary exchange rate model fails unless multiple structural breaks are allowed, suggesting that the parameters of the model change over time.

[5]In the theoretical literature, some authors examine the relationship between unconventional policies and the exchange rate. For example, based on a two country DSGE model, Adler *et al.* (forthcoming) studies theoretically the effects of cooperative and self-oriented unconventional policies on exchange rates.

2 Empirical framework

2.1 The monetary exchange rate model

Consider a parsimonious MAER model as in Taylor (1995) and Loría *et al.* (2010), among others. To begin, the purchasing power parity is assumed to hold:

$$\varepsilon = p - p^*, \tag{1}$$

where ε denotes the natural logarithm of the nominal exchange rate, and p and p^* denote, respectively, the natural logarithms of the domestic and foreign price indices. Moreover, we assume money market equilibriums in each country

$$p = m - l, \tag{2}$$
$$p^* = m^* - l^*, \tag{3}$$

where m and m^* denote, respectively, the natural logarithms of the domestic and foreign money supply, and l and l^* denote, respectively, the domestic and foreign money demand. The money demand in each country is assumed to be proportional to real income in that country and to be inversely proportional to the interest rate in that country, such that

$$l = \gamma y - \delta r, \tag{4}$$
$$l^* = \gamma y^* - \delta r^*, \tag{5}$$

with $\gamma, \delta > 0$, where y and y^* denote, respectively, the natural logarithms of domestic and foreign real income, and r and r^* denote, respectively, the domestic and foreign nominal interest rates. Note that we assume the semi-elasticity of the nominal interest rate.

It follows from the above that

$$\varepsilon = (m - m^*) - \gamma(y - y^*) + \delta(r - r^*). \tag{6}$$

In sum, the monetary exchange rate model predicts that the nominal exchange rate is positively correlated with the money supply differential and interest rate differential, and is negatively correlated with the real income differential.

While M2 money stock is used as a proxy variable of m in extant literature, our purpose is to assess the difference between M2 money stock and the monetary base. To achieve this, we consider their relationship

$$m_s = \mu + m_b, \tag{7}$$

$$m_s^* = \mu^* + m_b^*, \tag{8}$$

where m_s is the natural logarithm of money stock, m_b is that of the monetary base, and μ is that of the money multiplier. Hence, our underlying empirical models can be written as the following two equations:

$$\varepsilon = \beta_s(m_s - m_s^*) - \gamma(y - y^*) + \delta(r - r^*), \tag{9}$$

$$\varepsilon = \beta_b(m_b - m_b^*) + \beta_\mu(\mu - \mu^*) - \gamma(y - y^*) + \delta(r - r^*). \tag{10}$$

2.2 Decomposing the time–frequency coefficients

In almost all previous literature, the coefficients of (9) are estimated by traditional regression and cointegration analyses. However, as mentioned in our introduction, the coefficients can differ over time and across frequencies in the two equations if money stock and the monetary base exhibit different behaviors at each time and frequency. To formally demonstrate this, as in Aguiar-Conraria *et al.* (2018), we use the partial wavelet gain to serve as an equivalent to the regression coefficient for each time and frequency.

To explain the partial wavelet gain, we start with the continuous wavelet transform for the time series $x(t)$

$$W_x(\tau, s) = \int_{-\infty}^{\infty} x(t)\tilde{\psi}^*_{\tau,s}(t)dt, \tag{11}$$

where s denotes the scaling factor controlling wavelet length, τ denotes the translation parameter controlling wavelet location in time, the asterisk denotes a complex conjugation, and $\tilde{\psi}$ is the wavelet daughters obtained by scaling and shifting the mother wavelet ψ

$$\tilde{\psi}_{\tau,s}(t) = \frac{1}{\sqrt{|s|}}\psi\left(\frac{t-\tau}{s}\right), \quad s, \tau \in \mathbb{R}, s \neq 0. \tag{12}$$

Note that the wavelet is compressed (stretched), when the absolute value of s is less (more) than one. For our empirical purpose, we specify the mother wavelet as the Morlet wavelet, $\psi_{\omega_0}(t) = \pi^{-1/4}e^{6it}e^{-t^2/2}$, where i denotes an imaginary unit (i.e., $i^2 = -1$).

To introduce the partial wavelet gain, we now consider many time series, $x_1(t), x_2(t)$, $\cdots$, $x_p(t)$, where p is an integer more than 2. Suppose an integer j $(2 \leq j \leq q)$ and the set such that $\boldsymbol{q}_j = \{2, 3, \cdots, p\} \setminus j$. Then, we can write the complex partial wavelet coherency of $x_1(t)$ and $x_j(t)$ after controlling for all the other series as

$$\varrho_{1j.\boldsymbol{q}_j} = -\frac{\boldsymbol{S}^d_{j1}}{\sqrt{\boldsymbol{S}^d_{11}}\sqrt{\boldsymbol{S}^d_{jj}}}, \tag{13}$$

where $\boldsymbol{S}$ is a $(p \times p)$ Hermitian matrix such that $\boldsymbol{S} = \{S_{kj}\}^p_{k,j=1} = \{\Theta(W_{x_k x_j})\}^p_{k,j=1}$, and $\boldsymbol{S}^d_{kj}$ is the cofactor $\boldsymbol{S}^d_{kj} = (-1)^{k+j} \det \boldsymbol{S}^j_k$, in which $\boldsymbol{S}^j_k$ is the submatrix formed by deleting the kth row and jth column. Note that Θ is a smoothing operator in both time and frequency, and $W_{x_k x_j}$ is the cross-wavelet transform $W_{x_k x_j}(\tau, s) = W_{x_k}(\tau, s) W^*_{x_j}(\tau, s)$.

Based on the complex partial wavelet coherency, the complex partial wavelet gain is

$$\mathscr{G}_{1j.\boldsymbol{q}_j} = \varrho_{1j.\boldsymbol{q}_j} \frac{\sqrt{\boldsymbol{S}^d_{jj}}}{\sqrt{\boldsymbol{S}^d_{11}}}. \tag{14}$$

Ultimately, the partial wavelet gain is given by the real part of the complex partial wavelet gain

$$\tilde{G}_{1j.\boldsymbol{q}_j} = \Re(\mathscr{G}_{1j.\boldsymbol{q}_j}) = \tilde{R}_{1j.\boldsymbol{q}_j} \frac{\sqrt{\boldsymbol{S}^d_{jj}}}{\sqrt{\boldsymbol{S}^d_{11}}}, \tag{15}$$

where $\tilde{R}_{1j.\boldsymbol{q}_j}$ is the partial wavelet coherency as in Ko and Funashima (forthcoming), such that

$$\tilde{R}_{1j.\boldsymbol{q}_j} = \Re(\varrho_{1j.\boldsymbol{q}_j}) = -\frac{\Re(\boldsymbol{S}^d_{j1})}{\sqrt{\boldsymbol{S}^d_{11}}\sqrt{\boldsymbol{S}^d_{jj}}}. \tag{16}$$

At each point of time-frequency space, (15) and (16) correspond, respectively, to the partial regression coefficients and partial correlation coefficients in the multiple linear regression of a dependent variable x_1 over x_j with $p-1$ the explanatory variables $x_2, x_3, \cdots, x_p$.[6]

3 Empirical analysis

3.1 Data description

For our estimation, we use monthly observations, and the sample is a post-Bretton Woods period January 1975 to June 2017. As a proxy variable of real income, industrial production is used. Except for the nominal exchange rate and interest rate, all the series are

[6] We use ASToolbox by Luís Aguiar-Conraria and Maria Joana Soares to estimate all the wavelet measures. The ASToolbox can be downloaded at `https://sites.google.com/site/aguiarconraria/joanasoares-wavelets/the-astoolbox`. Note that the present partial wavelet gain and coherency are different from those in Aguiar-Conraria *et al.* (2018), as we consider the real part to evaluate the sign.

seasonally adjusted. The nominal exchange rate of the Japanese yen/U.S. dollar (EXJPUS) is obtained from the St. Louis Fed FRED website. All U.S. data on M2 money stock (M2SL), the monetary base (AMBSL), industrial production (INDPRO), and the interest rate (TB3MS) and all the Japanese data on M2 money stock (MYAGM2JPM189S) and the interest rate (INTGSTJPM193N) are also taken from the FRED website.[7] The Japanese monetary base and industrial production can be found at the website of the Bank of Japan and Japan's Cabinet Office (Indexes of Business Conditions), respectively.

[Insert Figure 2 around here]

Figure 2 depicts the series of our dependent and explanatory variables. Most of the series behavior is naturally consistent with the visual inspection of Figure 2. A casual observation indicates that the M2 money stock differential is stable in the short-run and traces the long-run movement of the exchange rate, in general. In contrast, the monetary base differential fluctuates at higher frequencies after the 2000s, and comoves with the exchange rate in the short-run. The monetary base differential exhibits a rapid increase in a period around 2002-2006, due to quantitative easing introduced by the Bank of Japan. Following the late 2000s, it declines dramatically due to quantitative easing by the Fed. Thereafter, it increases considerably due to the Abenomics monetary policy and the concomitant Fed tapering.

3.2 Results on money supply

Having described the analytical framework and data, we now turn to the empirical results.[8] Before presenting the estimated regression coefficients as in (15), we start by examining the estimated correlation coefficients over a time–frequency space as in (16). To evaluate the positively significant time–frequency regions, we utilize Monte Carlo simulations. In doing so, following Aguiar-Conraria and Soares (2014) and many others, the surrogate series are generated by a fitted ARMA(1, 1) model, drawing errors that follow a Gaussian distribution.

[Insert Figure 3 around here]

Figure 3 shows the results of partial correlation coefficients for the exchange rate and money supply. In this figure, the positively significant regions at 5% and 10% significance

[7] The series of Japanese M2 money stock is linked after February 2017 by using data from the website of the Bank of Japan.

[8] When estimating (10), the money multiplier differential is divided into each country's money multiplier, since there is a strong positive correlation between the monetary base differential and the money multiplier differential.

levels are depicted, respectively, as orange and yellow contours. The dashed lines are border lines of the region affected by edge effects.[9] In the following, as in the business cycle literature, we use "short-run" to mean higher frequencies less than eight-year cycles and "long-run" to mean lower frequencies more than eight-year cycles.

Notable findings emerge from both the time and frequency perspective. The structural changes over time are common in both the cases of the money stock and the monetary base. Specifically, regardless of the two monetary aggregates, we can see that there are larger significant regions after the 2000s than before this. On the other hand, from a frequency perspective, this time-varying feature differs between the two. We find that in the money stock case, the larger regions emerge only in the short-run; however, in the monetary base case, they emerge both in the short- and long-run.

[Insert Figure 4 around here]

To investigate more formally how money supply affects the exchange rate, we next present the estimated coefficients for $(m_s - m_s^*)$ and $(m_b - m_b^*)$ in (9) and (10), which are calculated as the partial wavelet gain as in (15). Figure 4 shows the results. Note that in Figure 4, we report the results for two frequency bands: short-run frequencies (1.5-8 years) and long-run frequencies (8-16 years). The short-run frequencies correspond to a typical business cycle range as in Baxter and King (1999) and Christiano and Fitzgerald (2003). Unfortunately, as stated in Aguiar-Conraria *et al.* (2018), there is no appropriate significance testing for the wavelet gain, and they recommend that the statistically insignificant regions of coherency should be disregarded when evaluating the gain. Following their recommendation, we consider the results of the wavelet gain with reference to larger significant regions that can be confirmed in Figure 3.

As can be seen in the upper panel of Figure 4, we find that the short-run estimates of both money stock and the monetary base are very unstable over time before the 2000s, suggesting the exchange rate disconnect puzzle for money supply. On the other hand, the short-run estimates of both money stock and the monetary base are stable and positive after the 2000s. Moreover, it is worth emphasizing that the estimated coefficients for monetary base are larger than those for money stock after the mid-2000s, corresponding to the period in which the Bank of Japan and the Fed pursued quantitative easing policies. These short-run results are consistent with those of Figure 3. In the long-run results plotted in the lower panel of Figure 4, excluding the period before 1990s, the estimated coefficients for the monetary base are positive, but those for the money stock are negative, as expected from Figure 3.

[9] The edge effects mean that the results at the beginning and end of the sample periods are unreliable and stem from the finite length of the time series. Note that this problem stretches at lower frequencies. For more details of the edge effects, see, e.g., Aguiar-Conraria and Soares (2014).

[Insert Figure 5 around here]

It should be noted that the above short-run results are obtained by using a typical business cycle range (1.5-8 years). However, another strand of the literature uses a narrower range, three to eight years, as a business cycle frequency band. This includes, among others, Kydlarid and Prescott (1990) and Levy (2000). Moreover, especially in long-run results, wide-edge effects occur as shown in Figure 3. Hence, as a robustness check, Figure 5 reports the results on a narrower frequency band, in which short-run frequencies are set between 3-8 years and long-run frequencies are set between 8-12 years. For the most part, these reinforce the above conclusions. In the short-run, on this narrower frequency band, the difference between the monetary base and money stock is more evident after the mid-2000s. Although the short-run estimates for money stock exhibit larger values before the early 1980s, they are not statistically significant as shown in Figure 3. We notice that the long-run results mirror the above.

Our findings have several important implications. First, our outcomes suggest that introducing unconventional monetary policy, such as quantitative easing, enhances the relative role of the money supply in macroeconomic fundamentals. It is quite probable that the monetary base, rather than the money stock, gains importance in traders' minds, with the announcement of quantitative easing. Accordingly, the role of the monetary base would increase in the short-run, and the degree becomes larger compared with the money stock. Second, while previous studies use money stock to test the MAER model, we demonstrate that money stock has a limited role. In particular, we find that in the long-run, there is no positive correlation between the exchange rate and money stock throughout the period, meaning that the exchange rate fluctuation is disconnected from the money stock. Although most previous work employs cointegration analysis to study the long-run relationship between the exchange rate and money stock, our analysis reveals that those attempts are likely to fail to find a significant link.

3.3 Results on other fundamentals

Next, we present results on real income and interest rates. Although our primary interest is in money supply, it is meaningful to explore whether these fundamentals can explain exchange rate dynamics over time and across frequencies. This exploration could revisit the exchange rate disconnect puzzle, which is the discrepancy between the nominal exchange rate and macroeconomic fundamentals.

[Insert Figure 6 around here]

Figure 6 plots the significant regions of partial correlation coefficients for $(y - y^*)$ and $(r - r^*)$ as before. Panel A is the correlation between the exchange rate and real income, and the expected sign is negative in the MAER model. However, Panel B is the correlation with the interest rate, which is expected to be positive. Hence, negatively significant regions are shown in Panel A, and positively significant ones in Panel B.

In examining the real income results for the money stock model, negative and significant correlation is observed only in a short-run region from 1990 to the mid-2000s. This suggests that when using money stock, the long-run relationship between the exchange rate and real income cannot be found. Thus, the exchange rate disconnect puzzle can arise if we focus only on the long-run of money stock. However, for the monetary base model, there are additional significant short-run regions in a more recent period. Furthermore, albeit at the 10% level, we can see a negatively significant region after the 1990s in the long-run.

Turning to the interest rate results, regardless of the money stock or the monetary base model, we find few large significant regions in the time–frequency space excluding regions affected by edge effects. Overall, the relationship between the exchange rate and interest rate seems to be unstable and weak.

In sum, we cannot find stable and strong correlation with the exchange rate especially in the case of the interest rate, even if we analyze this from both the short- and long-run perspectives. In other words, as the extant literature on the exchange rate disconnect puzzle suggests, real income and interest rate are shown to be unstably connected with the exchange rate.

4 Conclusion

Money supply has been considered one of the relevant determinants of exchange rate behavior. However, the introduction of quantitative easing policy results in breaks in the money stock and monetary base nexus, heightening the need to reconsider the role of the money supply in exchange rate determination. Thus, the quantitative easing policy provokes new questions: Do sharp increases in the monetary base cause currencies to depreciate even without increases in money stock? Or, is money stock more relevant to exchange rate dynamics than the monetary base, even under the quantitative easing periods? Against the backdrop of Japanese and U.S. quantitative easing policies introduced after the 2000s, we argue that the correct methodology to answer these questions requires both time and frequency perspectives.

Our time–frequency results reveal that quantitative easing policies drive currency market traders to pay attention to the monetary base in the short-run. One notable point in the results is that the significant role of the monetary base is exceptionally stable throughout quantitative easing periods, while we find, on the whole, a weak and unstable relationship between the exchange rate and monetary fundamentals, as in the exchange rate disconnect puzzle literature. This implies that quantitative easing policies persistently enhance the role of the monetary base in the short-run exchange rate determination. Moreover, although the MAER literature focuses on the long-run role of money stock, our results show that the monetary base outperforms money stock in explaining the exchange rate in the long-run as well, meaning that the long-run validity of the Soros chart is supported.

The present results are limited in the assessment of the recent period especially at long-run frequencies, due to the edge effects. This limitation can be overcome by updating data as they become available. The issue should be pursued in our future research.

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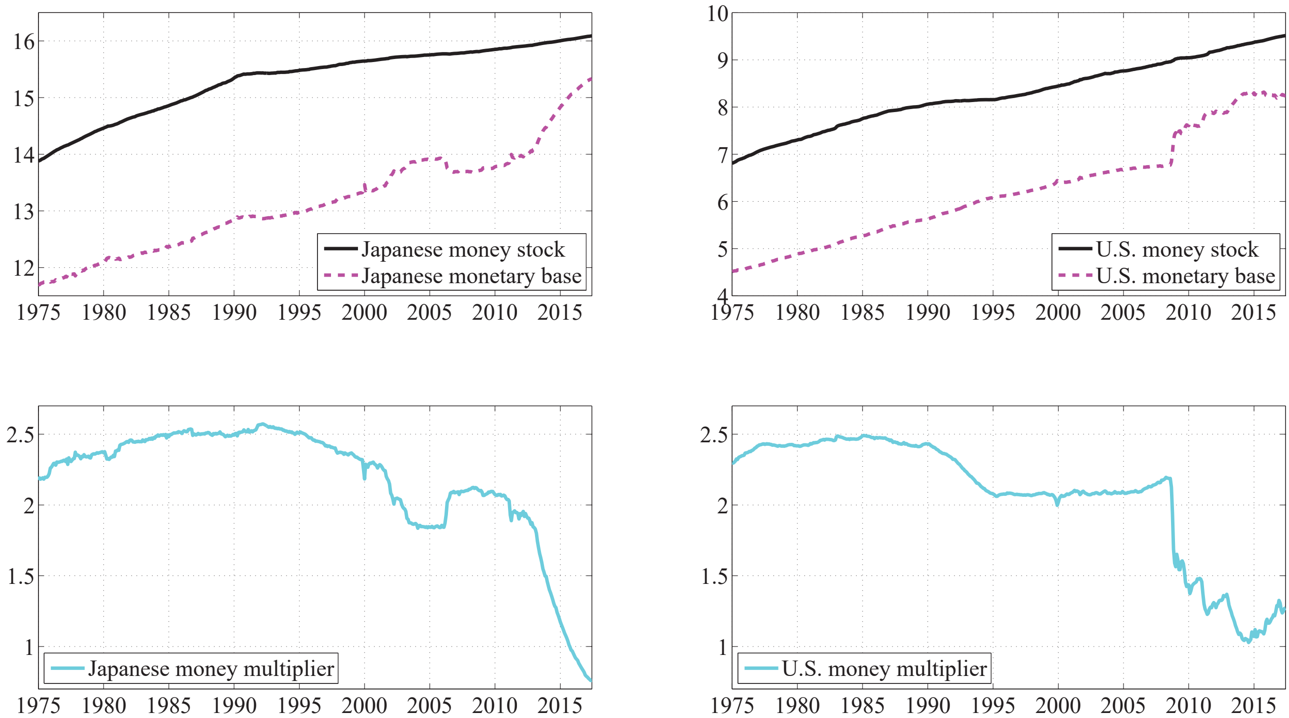

Figure 1: Money supply and money multiplier in Japan and the United States (log level)

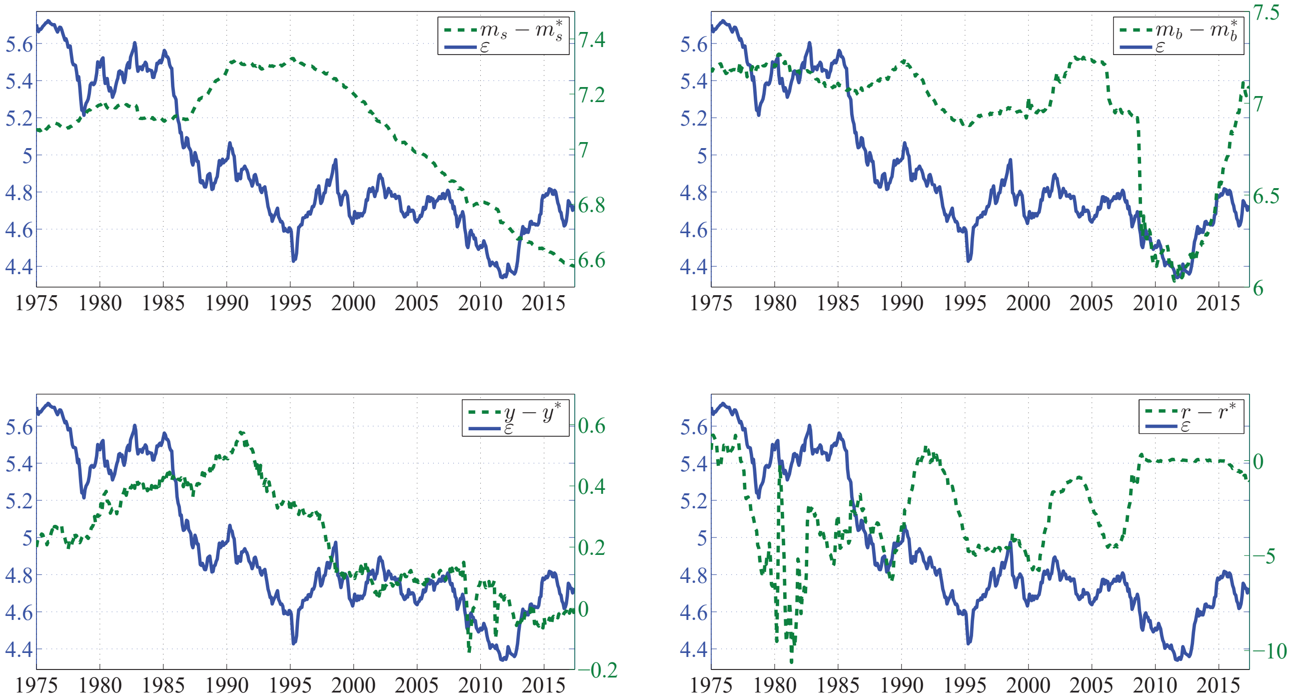

Figure 2: Japanese Yen/USD exchange rate and explanatory variables

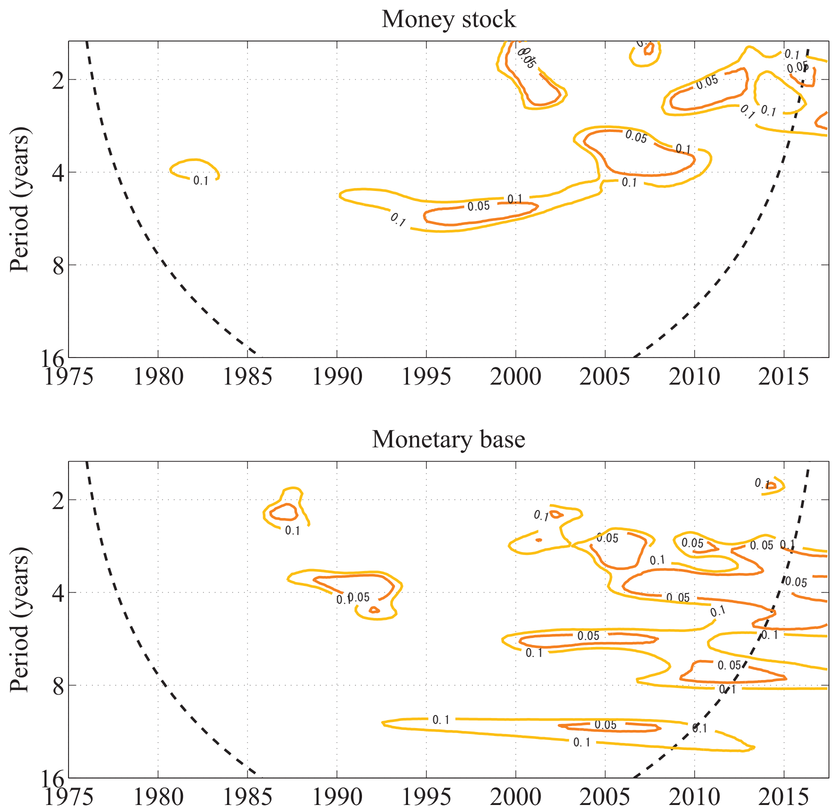

Figure 3: Significantly correlated regions of money supply

Notes: The positively significant regions at 5% and 10% significance levels are respectively depicted as orange and yellow contours. The dashed lines are border lines of the region affected by edge effects.

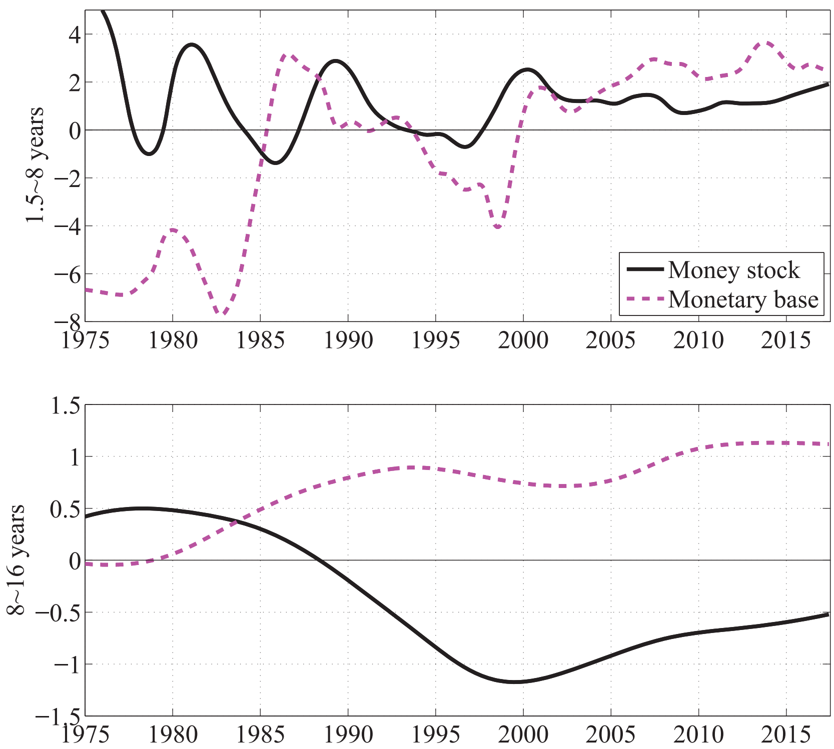

Figure 4: Estimation results of money supply coefficients

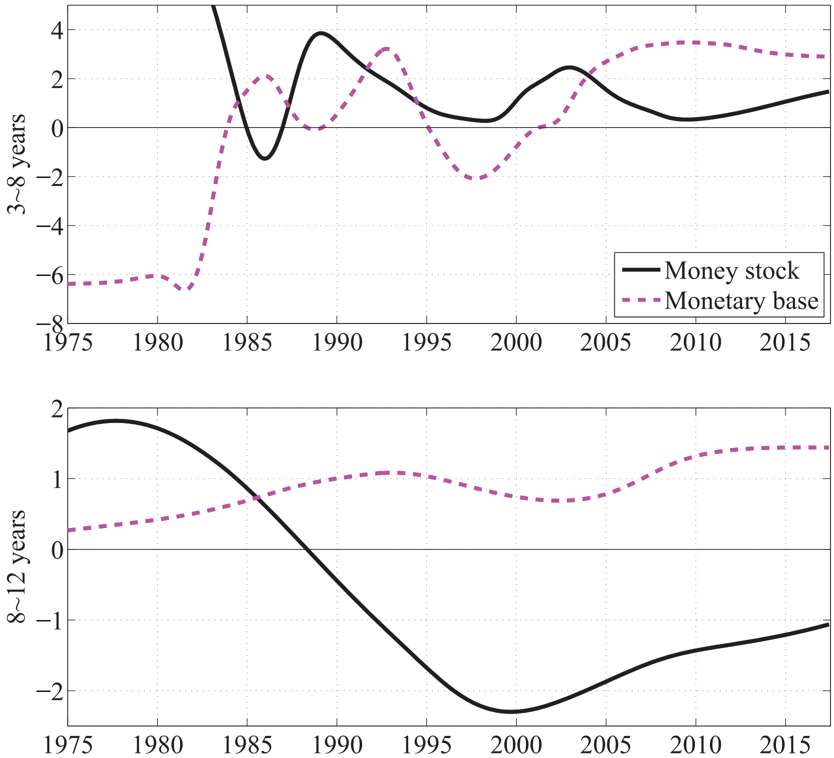

Figure 5: Estimation results of money supply coefficients in a narrower frequency band

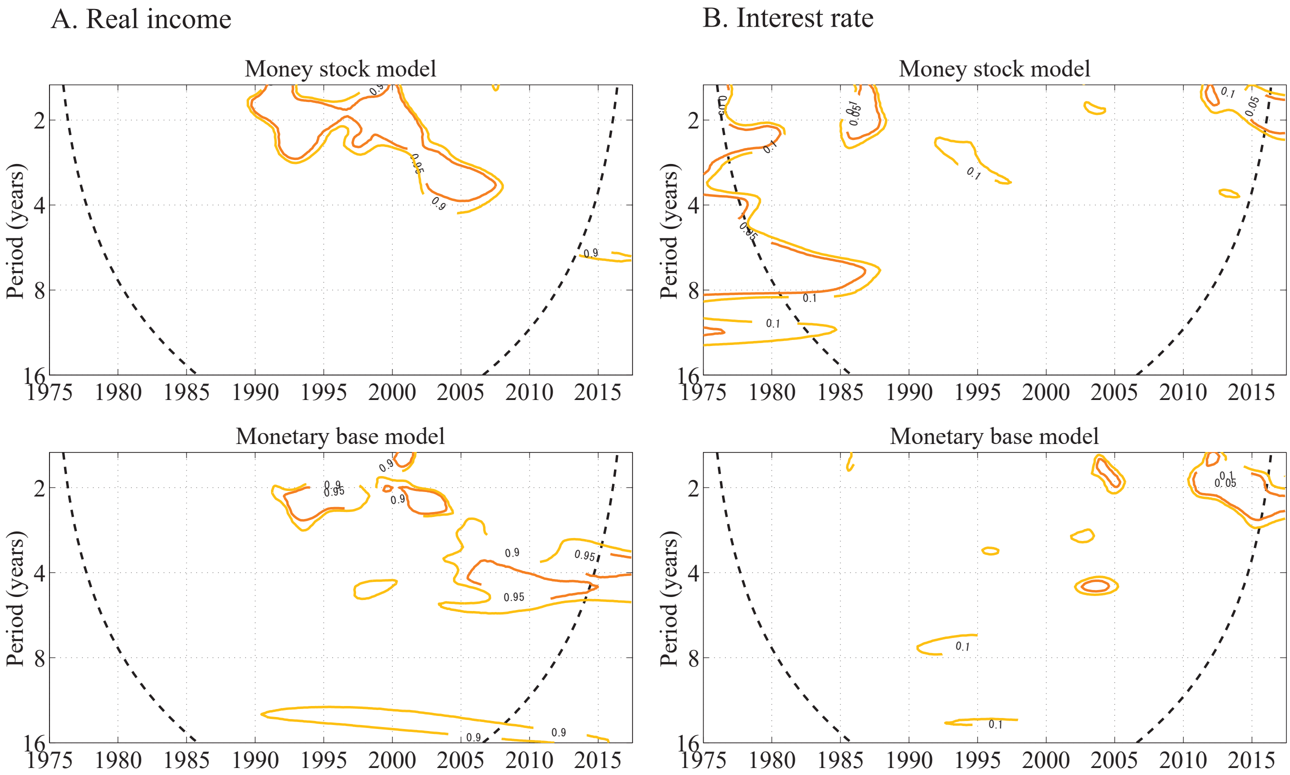

Figure 6: Significantly correlated regions of real income and interest rate

Notes: The negatively (positively) significant regions at 5% and 10% significance levels are respectively depicted as orange and yellow contours in Panel A (B). The dashed lines are border lines of the region affected by edge effects.