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The Effects of US and UK Quantitative Easing Policies on Exchange Rates: A Time Series Analysis

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Abstract

Facing liquidity trap problems, a number of industrialised countries, including the United States and the United Kingdom, have since 2008 implemented Quantitative Easing (QE) measures in an attempt to improve financing conditions in their overall economy. Although Quantitative Easing policies primarily act upon long-term interest rates and asset prices, they also have secondary effects on exchange rates. In a "currency war" context, some countries might be tempted to use QE as a protectionist weapon in a bid to achieve exchange rate depreciation. After identifying which QE transmission channels affect exchange rates, the paper proposes an empirical analysis of stylized facts and econometric tests on the United States and the United Kingdom. The results of time series analysis show that a stable long-term relationship exist between the exchange rate and the monetary base, with an increase in the latter leading to a depreciation in the domestic currency.

Keywords: Quantitative Easing, Exchange rate, Monetary base, Cointegration, VECM
JEL Classification Codes: E44, E51, E52, F31, F41

1. Introduction

For the USA's main trading partners (starting with China and Brazil), the Fed's decision on 13 September 2012 to engage a third quantitative easing programme (called QE3) [1] rekindled concerns whether the world's leading economic power was looking to use unconventional monetary policy measures to depreciate the dollar and make it into a trade weapon, even at the risk of triggering a

1. Quantitative Easing (QE) refers to several types of unconventional measures. According to a typology devised by B. Bernanke and al. (2004), this includes liability-oriented policies (i.e., measures intended to increase central bank liabilities hence the monetary base) as well as asset-oriented policies (i.e. measures intended to alter central bank assets, either by modifying their maturities or changing their nature). Quantitative Easing in its purest form corresponds to the creation of a monetary base through the purchase of government securities.

currency war. As noted by P. Artus (2010), the implementation of aggressive monetary policies "(probably) does not come from a desire for exchange rate depreciation but reflects instead a monetary policy's internal objectives (renewing the supply of credit, reducing long-term interest rates, increasing asset prices, sustaining expected inflation, etc.)". This is because when key rates are close to zero, as has been the case in the United States since December 2008, financing conditions can only be improved within an economy through the implementation of unconventional monetary policies inflating central banks' balance sheets. Thus, the balance sheet of the Federal Reserve, which has engaged in a massive purchase of long-term securities since late 2008 (amounting to more than $2 trillion between yearend 2008 and June 2011), has risen from 6% of GDP before the 2007-2008 financial crisis to nearly 20% at yearend 2011(appendix 1 features all of the Quantitative Easing measures adopted by the United States). Nevertheless, there is no doubt that Quantitative Easing policies have secondary effects on exchange rates that to some extent do resemble currency-based protectionism.

The United States is not the only country to have implemented unconventional monetary policies. For instance, the Bank of England, and more recently, the Central Bank of Japan have also engaged in massive purchases of government securities in a bid to stimulate growth and stave off deflation (cf. tables 8 and 9 appendix I) [2]. Following this, the Bank of England's balance sheet grew from less than 7% of GDP before the crisis to nearly 24 % in june 2012. Like the United States, England and Japan might have been accused of manipulating their exchange rates provide that these countries' currencies would depreciate in the wake of these Quantitative Easing policies.

A number of studies have measured the effects of Quantitative Easing policies on asset prices and interest rates (Gagnon and al., 2010; D'Amico and King, 2010; Doh, 2010; Hamilton and Wu, 2010; Wright 2011)[3], but few have focused on how their policies affect exchange rates. The only systematic study in this area covers Japan's experience with Quantitative Easing between 2001 and 2006 (Terai and al. 2005). Findings from this study demonstrate that Japan's monetary base, compared to that of the USA, had a significant effect on the yen's nominal exchange rate against the dollar. The questions arising at this level relate to the main transmission channels by means of which Quantitative Easing policies affect exchange rates; the effects on the Dollar when the United States implement an aggressive monetary policy; and whether Quantitative Easing measures necessarily lead to currency-based protectionism. The present text will try to provide certain elements of response. After surveying the main channels that Quantitative Easing uses to act upon exchange rates, we conduct an empirical study on the United States and the United Kingdom to assess recent unconventional monetary policies' effects on exchange rates.

2. The Transmission Channels Between Quantitative Easing and Exchange Rates

Quantitative Easing has an indirect effect on exchange rates through its impacts on other variables, mainly long-term interest rates, liquidity and inflation rates.

- **Transmission via long-term interest rates**

In theory, where a central bank's policy is to purchase financial assets with a long maturity (long-term government securities, government agency debt, asset-backed securities and corporate bonds), this should lead to lower long-term interest rates and a flattening of the yield curve. There are basically three theoretical mechanisms underlying this process. Firstly, the central bank's asset purchase should reduce the supply of long-term securities that are available to investors. If we assume that the demand for long-term securities remains unchanged, the excess of demand over supply resulting from Quantitative Easing should lead to higher prices for longer-maturity assets, and to a fall

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2 The European Central Bank has also implemented unconventional measures but ones that are mainly aimed at supplying banks with liquidity and enabling Eurozone countries that are currently struggling to refinance themselves to do so at a reasonable rate

3 Most of these studies show that QE measures significantly reduced long-term government bond yields.

in long-term interest rates. Secondly, Quantitative Easing has a signalling effect for economic agents (Bernanke and al. 2004). By engaging in such policies, central banks are manifesting their desire to maintain intervention rates at relatively low levels for a sufficiently long period of time. If the markets trust this commitment, they will expect lower short-term interest rates in the future[4]. Long-term rates will fall in turn, due to the fact that they are a reflection of expected future short-term rates. Thirdly and finally, central bank purchases have beneficial effects on financial markets that find themselves in a situation of stress. The spread between US mortgage rates and T-Bond yields rose sharply towards yearend 2008 at the worst of the financial crisis, before falling rapidly when the Fed announced its intention to purchase MBS.

What effects do lower long-term rates have on exchange rates?

A fall in a country's long-term domestic interest rates should be accompanied by a lower spread between long-term rates at home and abroad (the assumption here being that long-term rates abroad remain unchanged). In line with the uncovered interest rate parity (UIP), markets should expect the domestic currency to appreciate over the long run in this instance. If we also assume that the equilibrium long-term exchange rate remains unchanged, the domestic currency should depreciate immediately, as per the Dornbusch Overshooting model (1976) that considers regressive exchange rate expectations $:\dot{s}^a = \theta(\bar{s} - s)$, with $\dot{s}^a$ the currency's expected rate of variation, $\bar{s}$ the long-term equilibrium exchange rate corresponding to the Purchasing Power Parity (PPP) exchange rate, and s the current exchange rate where the national currency is being quoted on an indirect basis. In this equation, markets will anticipate an appreciation of the future spot exchange rate ($\dot{s}^a$ <0), if and only if the current exchange rate depreciates more than the long-term equilibrium implies ($s>\bar{s}$). The indication here would be that overshooting has occurred. This analytical framework, based on UIP, is particularly appropriate for explaining long-term interest rates' impact on exchange rates. Indeed, according to the most recent empirical studies in this area (Chinn and Meedith 2005), it is easier to verify UIP over the long-term (more than one year) than in the short run.

Recent experiences in the United States and the United Kingdom show that Quantitative Easing policies have in actual fact been able to reduce long-term interest rates and led to exchange rate depreciation, as predicted above. For instance, the Fed's liquidity injection programme, involving the purchase of $1.725 trillion in long-term securities between yearend 2008 and March 2010, should have caused something like a 50 basis point drop in long-term rates (Gagnon and al. 2010; Chung and al. 2011)[5]. As expected under UIP, the announcement of these Quantitative Easing measures caused the Dollar to depreciate immediately (Neelly 2011). At the same time, it is worth noting that the American currency's effective depreciation was less than that what might have been expected under UIP (Table 1). As such, when on 18 March 2009 the Fed announced its intention of purchasing an extra $750 billion in MBS, $100 billion in agency debt and $300 in T-Bonds, the Dollar should have depreciated by 6.16% against the Euro according to UIP, in line with the 20-point drop in 10-year T-bond yields. In reality, however, it only fell by 4.93%. The announcement of QE2 also caused the Dollar to depreciate following the fall in long-term US interest rates, but significantly this particular transmission channel lost much of its intensity. Thus, according to simulations undertaken by Chung and al. (2011), the overall impact of QE2 on 10-year US rates should have been no more than 15 basis points. Yet long-term US rates actually rose after QE2's concrete implementation. This phenomenon has been explained in different ways (Mufteeva and Julien 2011). Reacting through higher rates, the markets were showing disappointment with the size of the second Quantitative Easing programme. Yet American officials preferred to interpret higher long-term rates as the sign of agents' improving expectations regarding US growth. Lastly, the deterioration in US government debt quality also put upwards pressure on long-term American rates.

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4 If the central bank does not meet its commitments, it will be exposed to a significant risk of capital losses because it would have "loaded" its balance sheet with long-term securities (Loisel and Mésonnier, 2009).

5 According to Chung and al. (2011), US intervention rates should have fallen by 200 basis points to generate an equivalent fall of 50 basis points in 10-year T-Bond yields.

The Quantitative Easing policy that Britain implemented between March 2009 and yearend 2010 involved the Bank of England purchasing £200 billion in assets, mainly comprised of Gilts (UK government bonds). This also led to a fall in long-term rates and a depreciation of Sterling. According to a study by Joyce et al (2010), Gilt yields dropped on average by 100 basis points following the announcement of these Quantitative Easing measures (cf. table 8, Appendix I), with falls ranging from 50 to 120 basis points depending on the securities' maturity. Given this fall in interest rates and in light of UIP, the authors consider that Sterling should have depreciated by 8%. Adding up the exchange rate variations that followed the announcement of these Quantitative Easing measures, Sterling's actual fall was only 4%. As happened in the United States, it is clear that the direction of exchange rate variations following Quantitative Easing measures was congruent what had been expected under UIP, but that the magnitude of the actual variation was less than what the relationship predicted.

- **Effects of agents' portfolio reallocation decision resulting from the added liquidity**

One effect of these unorthodox monetary policies was to increase liquidity. Where economic agents consider that liquidity created via Quantitative Easing constitutes a poor substitute for a central bank acquiring securities, they get rid of their surplus liquidity by purchasing other domestic assets (shares, property or bonds other than those mentioned above) along with foreign assets. This should culminate in upwards pressures on the price of these assets and downwards pressures on the national currency[6]. Unlike the effects specified above, effects relating to agents' portfolio reallocation decisions do not manifest immediately. This is because such actions take a relatively long time to unfold. The experience of the United States demonstrates, on the other hand, that a Quantitative Easing policy can lead relatively quickly to significant capital flows into emerging markets. Such flows fell sharply in 2008 but have been resurgent since, causing the Dollar to depreciate against the currencies of these countries, which have "started again to accumulate foreign exchange reserves that are largely invested in Treasuries to avoid excessive appreciation of their national currencies" (Artus 2011).

Table 1: Effects of Quantitative Easing in the United States on Dollar rates, adjusted for interest rate parity (%)

	Observed variations						**Exchange rate variations expected under UIP**	
	AUS/USD	**CAD/USD**	**EUR/USD**	**JPY/USD**	**GBP/USD**	**USD**	**EUR/USD**	**GBP/USD**
•Dates when Federal Reserve purchased long-term securities								
25 November 2008	-0.53	-0.22	-0.04	-1.42	-1.25	-0.69	-5.12	-2.96
1 December 2008	1.77	1.23	-0.03	-2.41	3.36	0.79	-1.53	-0.82
16 December 2008	-4.93	-2.94	-4.86	-3.75	-1.29	-3.55	-4.53	-1.96
28 January 2009	1.64	-0.21	1.73	0.97	-1.03	0.62	1.06	2.97
18 March 2009	-3.61	-2.50	-4.93	-4.17	-3.37	-3.71	-6.16	-6.25
Total	**-5.66**	**-4.64**	**-8.13**	**-10.7**	**-3.58**	**-6.54**	**-16.28**	**-9.02**
• Dates when Federal Reserve sold long-term securities								
12 August 2009	-1.50	-1.15	-0.95	-0.58	-0.60	-0.95	0.68	0.04
23 September 2009	0.90	1.85	0.97	0.02	1.90	1.13	0.60	0.45
4 November 2009	-0.91	-0.17	-1.11	0.47	-1.06	-0.55	-1.36	-1.46
Total	**-1.51**	**0.53**	**-1.09**	**-0.09**	**0.24**	**-0.37**	**-0.08**	**-0.97**

(+) Dollar appreciation
(-) Dollar depreciated
Source: Adapted from Neely (2011)

6 Breedon et al.(2011) find that the UK's initial 2009-10 QE Programme significantly lowered governement bond yields through the portfolio balance channel by around 50 points.

- **Transition through inflation rates**

A massive injection of liquidity can resurrect expectations of long-term inflation. As noted by Betbeze (2010), an overly aggressive monetary policy "raises issues of trust in control over the new tools that the central bank has created, and also in terms of its capacity to reduce them, even as its assets continue to grow". Where this policy undermines the central bank's credibility, agents will start to expect higher future inflation. Higher imported inflation resulting from a depreciation of the national currency – as per the mechanisms detailed in the two points above – will reinforce agents' inflation expectations. Lastly, in line with Purchasing Power Parity , an increased spread between inflation expectations for the home and the foreign country should cause agents to expect the national currency to depreciate in the future. Note however that the inflation risks associated with Quantitative Easing are relatively moderate as long as the underlying inflation remains under control.

In theory and in line with the aforementioned mechanisms, a Quantitative Easing policy should cause exchange rate depreciation. What we suggest is an empirical study verifying the global impact of recent Quantitative Easing measures on exchange rates.

3. Empirical Analysis of Quantitative Easing's Global Effects on Exchange Rates

Our empirical study covered the United States and the United Kingdom. After using chart evidence to highlight the correlation between exchange rates and the monetary base (been selected as the variable representing Quantitative Easing), we apply time series analytical tools.

The positive correlation between the increased monetary base and the depreciation of the national currency appears clearly in the United States (Fig.1). More specifically, what becomes evident is that the positive correlation between growth in the US monetary base and the depreciation of the Dollar in effective terms has accentuated since the Fed has adopted Quantitative Easing measures (Fig. 1b). The coefficient of correlation between the preceding variables hit 0.80 between March 2009 and February 2012, against 0.56 between January 2000 and February 2009.

Conversely, in the United Kingdom, the policy of Quantitative Easing had contradictory effects on the exchange rate (Fig. 2). For instance, during 1Q 2009, a strong rise in the monetary base coincided with Sterling's appreciation against the Dollar and in effective terms. From August 2010 through September 2011, Sterling depreciated even as the monetary base fell. On the other hand, between September 2011 and February 2012, the monetary base's expansion coincided with the pound's depreciation versus the dollar.

Figure 1: Quantitative Easing in the United States and Dollar rates

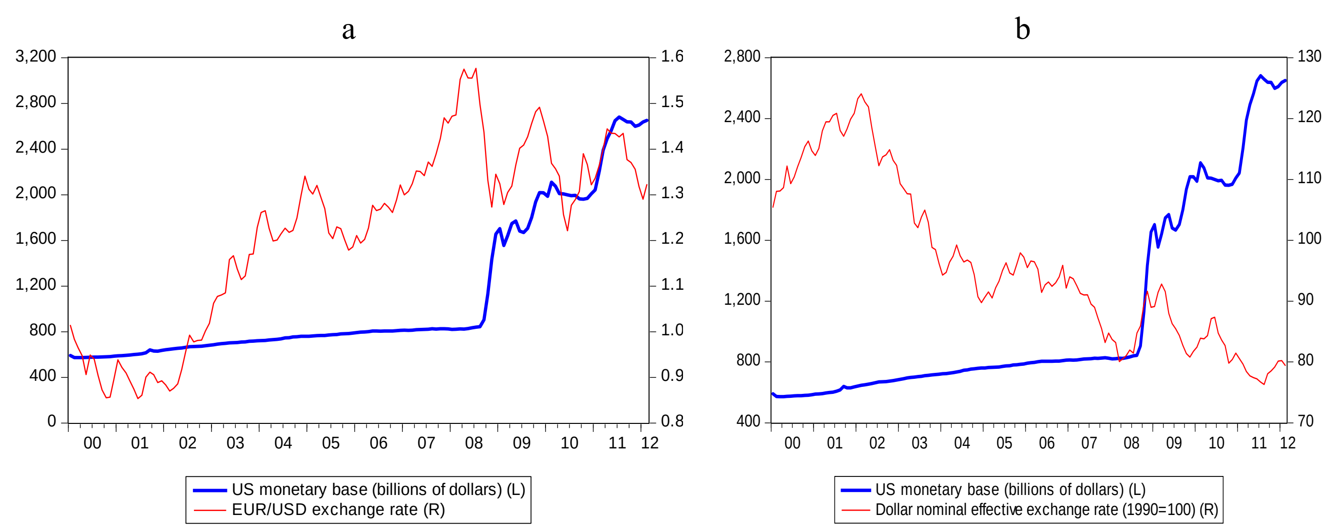
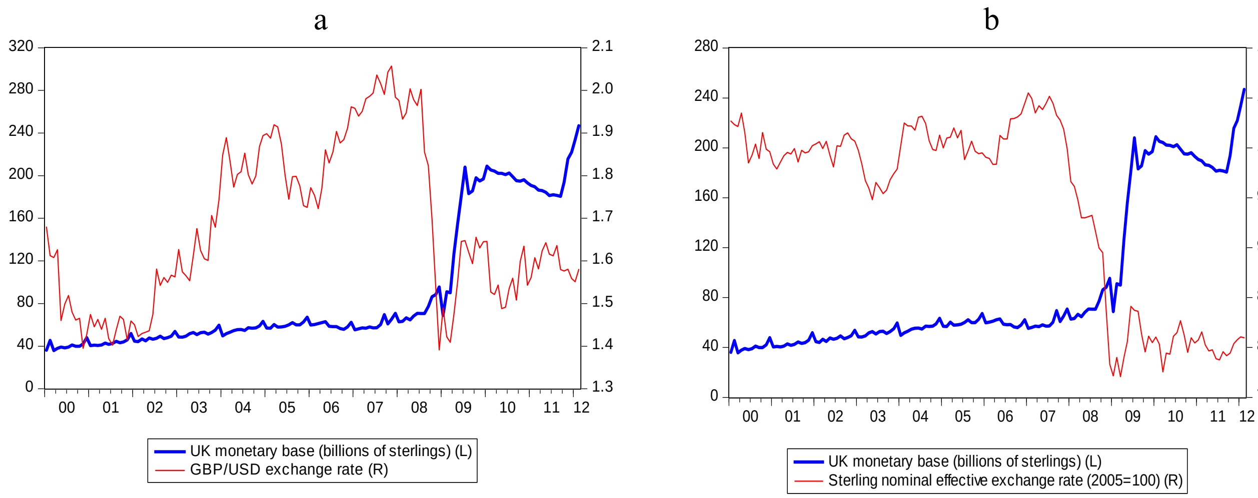


Figure 2: Quantitative Easing in the United Kingdom and Sterling rates



Source: Datastream and Bank of England

To estimate the effects of Quantitative Easing on exchange rates more precisely, we start, in line with the Monetary Approach to Exchange Rate (MAER) determination, by trying to ascertain whether a long-term relationship exists between the monetary base and the exchange rate – in which case, we would then go on to consider adjustment towards long-term equilibrium.

To test the existence of a long-term relationship between the exchange rate and the monetary base, we have used cointegration test. The cointegration relationship is estimated using the Johansen method. The trace statistic, which test the null hypothesis of r cointegration relationships against the alternative hypothesis of n (r < n), and the λ max statistic (max-eigenvalue statistic), which tests the null hypothesis of r cointegration relationships vs. the alternative hypothesis of r+1, are used. The tests below cover the US monetary base and dollar exchange rate (involving, in turn, the EUR/USD rate and the dollar's nominal effective exchange rate) as well as the UK monetary base and pound exchange rate (involving, in turn, the GBP/USD rate and the pound's nominal effective exchange rate). The series for the US monetary base, EUR/USD and GBP/USD exchange rates and the dollar's nominal effective exchange rate come from Datastream. For the UK monetary base and the pound's nominal effective exchange rate, the series come from the Bank of England. The monetary base series have been seasonally adjusted. All of these series are expressed in logarithms. The tests ran from January 2006 to February 2012.

Before doing the cointegration tests between the monetary base and the exchange rate, we must verify that the two series in question are non-stationary in levels and stationary in first differences (i.e. integrated of order 1, I(1)). Towards this end, we conducted unit root tests using customary Augmented Dickey and Fuller (ADF) and Phillips and Perron (PP) statistics. The findings from these tests (Table 2) indicate that all of the monetary base and exchange rate series are non-stationary in levels and stationary in first differences. As such, they are integrated of order 1.

In the presence of structural breaks, however, the aforementioned tests lose some of their power (Perron, 1989; Zivot and Andrews, 1992; Lumsdaine and Papell, 1997), meaning that traditional tests might, wrongfully, accept the unit root hypothesis. The series being considered here feature trend breaks that could invalidate findings from the ADF and PP tests. To remedy this problem, unit root tests were conducted incorporating these structural breaks. More specifically, we used Clemente and al's test (1998), which offers the possibility of incorporating two endogenous break dates, i.e. ones that are automatically determined by the procedure. The findings (Table 3) show that, despite the presence of structural breaks in the monetary base and exchange rate series, we cannot reject the unit root hypothesis. This means that all of the series are non-stationary in levels.

Table 2: Unit root tests

Series	Augmented Dickey-Fuller (ADF)		Phillips et Perron (PP)	
	Level First	difference	Level	First difference
ln US monetary base	-2.05	-5.31**	-1.99	-3.50*
ln EUR/USD	-2.59	-6.47**	-2.39	-6.40**
ln USD nominal effective exchange rate	-2.61	-7.11**	-2.48	-7.11**
ln UK monetary base	-1.86	-4.61**	-2.01	-8.99**
ln GBP/USD	-2.09	-7.65**	-2.39	-7.76**
ln Sterling nominal effective exchange rate	-1.69	-6.60**	-1.66	-6.60**

Source: Authors
Note: The auxiliary regression is run with an intercept and a time trend, both for the level and first differenced series.
*and ** indicate that the null hypothesis (non-stationarity) is rejected at 5% and 1% significance levels.

Table 3: Clemente-Montanés-Reyes test with structural breaks, additive outliers model

Series	Number of break(s)	Break dates	Model	Constant	DU1	DU2	Rho-1	Conclusion
ln US monetary base	2	Feb.2009 Jan. 2010	AR(12)	6.78	0.72 (0.000)	0.23 (0.001)	-1.31[a]	Non-stationary
ln UK monetary base	2	Sept.2007 Feb.2009	AR(5)	4.08	0.20 (0.000)	0.96 (0.000)	-2.67[a]	Non-stationary
ln EUR/USD	2	Dec.2007 Nov.2011	AR(11)	0.27	0.12 (0.000)	-0.008 (0.000)	-2.77[a]	Non-stationary
ln USD nominal effective rate	2	June 2007 Nov.2010	AR(0)	4.54	-0.09 (0.000)	-0.07 (0.000)	-3.03[a]	Non-stationary
ln GBP/USD	1	July 2008	AR(8)	0.66	-0.20 (0.000)	-------	-0.76[b]	Non-stationary
ln Sterling nominal effective rate	2	Dec.2007 Aug 2008	AR(11)	4.63	-0.09 (0.000)	-0.15 (0.000)	-1.36[a]	Non-stationary

Source: Authors
Note: The numbers in parentheses are critical probalities of the Clemente test.
The statistics of unit root tests are given in the column Rho-1.
[a]The critical value at 5% is -5.49 [b]The critical value at 5% is -3.56

At this point, we can reasonably conduct the cointegration tests[7]. The results of these tests for the United States (Table 4) and the United Kingdom (Table 5) show that, irrespective of the parity used:

- the null hypothesis of absence of cointegration (r = 0) between the monetary base and the exchange rate, is rejected (at the 5% level in most cases),
- the null hypothesis of one cointegration relationship between the monetary base and the exchange rate is accepted, at the 5% level.

As such, a cointegration relationship does exist between the monetary base and the exchange rate, in both the USA and the UK. The long-term relationships associated with these figures can be found in Table 6 (covering the four cointegration relationships in question here, three of which are statistically significant). Within these specifications, the estimated coefficients all have the sign that theory predicts. Thus, over the long-term a 10 % rise in the domestic monetary base led to a depreciation of 1.1% in the dollar's nominal effective exchange rate, and of 1.9 % in the pound's nominal effective exchange rate.

The stability of these relationships should also be scrutinised. Given that the variables considered in this study are I(1) and that a cointegration relationship exists beween the exchange rate and the monetary base, what we need to estimate is the Vector Error Correction Model (VECM). The VECM captures the adjustment of variables to restore long-run equilibrium.

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7 We first determined the optimal number of lags p in the Var(p) model using the Akaike information criteria.

Table 4: Test for existence of cointegrating vectors using Johansen approach –United States

Test type	Trace/Max-Eigen Statistic	5 % Critical Value	10 % Critical Value	Probability	Hypothesized number of CE's
Model 1[1] :	**ln EUR/USD**	**ln US monetary base**			
Trace	14.27	15.49	13.43	0.0757	None**
	0.97	3.84	2.71	0.3255	At most 1
Max-Eigen	13.31	14.26	12.30	0.0704	None**
	0.97	3.84	2.71	0.3255	At most 1
Model 2[1] :	**ln USD nominal effective rate**		**ln US monetary base**		
Trace	16.58	15.49	13.43	0.342	None*
	0.39	3.84	2.71	0.5296	At most 1
Max-Eigen	16.18	14.26	12.30	0.0246	None*
	0.39	3.84	2.71	0.5296	At most 1

Source: Authors
Note: [1]The test assume a linear determinist trend in the data
*denote rejection of the hypothesis at the 0.05 level
**denote rejection of the hypothesis at the 0.10 level

The estimable VECM in this study consists of the following equations:

$$\Delta e_t = \alpha_1 + \rho_1 z_{1t-1} + \sum_{i=1}^{n} \beta_{1i} \Delta e_{t-i} + \sum_{i=1}^{n} \gamma_{1i} \Delta mb_{t-i} + \omega_t \qquad (1)$$

$$\Delta mb_t = \alpha_2 + \rho_2 z_{2t-1} + \sum_{j=1}^{m} \beta_{2j} \Delta mb_{t-j} + \sum_{j=1}^{n} \gamma_{2j} \Delta e_{t-j} + \vartheta_t \qquad (2)$$

where Δ_{et-i} and Δmb_{t-i} are first differenced series of exchange rate and monetary base (in logarithms) at time t-i; i=1,....n, respectively; z_{1t-1}, z_{2t-1} are error correction terms; $\omega_t et \ \vartheta_t$ are white noise. Given the existence of a long-term relationship between the exchange rate and the monetary base, the error correction term (ECT) capture adjustments to the long-run equilibrium in the system, when a shock disrupts the long relationship. The higher the absolute value of the z_{it-1} coefficient, the quicker the adjustment towards the long-term equilibrium. The principal results of estimating equations (1) and (2) are being presented in appendix 2 (the Ljung-Box Q statistics, no published here, show that the residuals are white noise).

Table 5: Test for existence of cointegrating vectors using Johansen approach –United Kingdom

Test type	Trace/Max-Eigen Statistic	5 % Critical Value	10 % Critical Value	Probability	Hypothesized number of CE's
Model 1[1] :	**ln GBP/USD**	**ln UK monetary base**			
Trace	15.39	15.49	13.43	0.0518	None**
	0.007	3.84	2.71	0.9320	At most 1
Max-Eigen	15.39	14.26	12.30	0.0331	None*
	0.007	3.84	2.71	0.9320	At most 1
Model 2[1] :	**ln GBP nominal effective rate**		**ln UK monetary base**		
Trace	22.41	15.49	13.43	0.0039	None*
	0.61	3.84	2.71	0.4349	At most 1
Max-Eigen	21.80	14.26	12.30	0.0027	None*
	0.61	3.84	2.71	0.4349	At most 1

Source : Authors
Note : [1]The test assume a linear determinist trend in the data
*denote rejection of the hypothesis at the 0.05 level
**denote rejection of the hypothesis at the 0.10 level

Table 6: Cointegrating equations

ln EUR/USD = 0.160 + 0.021 ln US Monetary Base (0.54)
ln US Nom. Eff. Rate = 5.252 – 0.111 ln US Monetary Base (-4.67)*
ln GBP/USD = 1.279 – 0.158 ln UK Monetary Base (-6.36)*
ln GBP Nom. Eff. Rate = 5.387 – 0.192 ln UK Monetary Base (-13.67)*

Source : Authors

Note : The numbers in parentheses are the t-statistics. *denote statistical significance at the 0.01 level

The error correction term is negative and significant in all of the equations explaining the exchange rate variations, regardless of the rate being used. This intimates that a stable long-term relationship between the exchange rate (dependent variable) and the monetary base (independent variable) exists. The speed of the exchange rate's adjustment depends on the parity being considered, with the speeds of adjustment between -0.12 to -0.24. On the other hand, the error correction term is not significant in most of the equations used to explain variations in the monetary base (except for the equation explaining variations in the British monetary base in light of variations in the pound's actual nominal exchange rate). What this intimates is that the monetary base is not involved in the adjustment towards a long-term equilibrium. The hypothesis that the monetary base is (slightly) exogenous can therefore be accepted (ie long run causality run from monetary base variations to exchange rate variations). Lastly, the error correction model can be reduced to a single equation (equation 1), except when we consider the pound's nominal effective exchange rate[8].

4. Conclusion

Based on the recent experiences of the United States and the United Kingdom, the present article has tried to ascertain whether Quantitative Easing policies have an effect on exchange rates. To provide elements of response to this question (whose important is exemplified by the presence of this topic in currency war debates), we have relied on time series analytical tools. The findings show that a stable long-term relationship exists between the exchange rate (endogenous variable) and the monetary base, with an increase in the latter leading to a depreciation in the domestic currency. This finding is verified in both the USA and the UK, notably when the effective nominal exchange rate is taken into consideration. The thesis that Quantitative Easing policies might be used for protectionist purposes in order to get a currency to depreciate is therefore validated.

Under these conditions, it is possible to envisage a number of extensions complementing this evaluation of the effects of Quantitative Easing on exchange rates. First, an empirical study using more detailed data (compiled on a daily basis) should help to specify the effects of Quantitative Easing announcements on exchange rates. Given that exchange rates are highly dependent on agents' expectations of future changes in economic policy, it would be interesting to see how exchange rates react to Quantitative Easing policies when these have been anticipated by economic agents.

[8] The VECM model can also be used to test short-term causality in Granger's sense of the term. The tests, based on F statistics, consist in setting the coefficients of all lagged differences of each of the right-hand size variables in equations (1) and (2) to zero. For example, in equation (1), a test of short-run non-causality from mb to e consist in testing wether the coefficients of the lagged differences of the mb variables ($\sum_{i=1}^{n} \Delta mb_{t-i}$) are all equal to zero : $\gamma_{11} = \gamma_{12} = ….. = \gamma_{1n} = 0$.

The results (no published here) show that bi-directional causality exists between exchange rate and monetary base.

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Appendix I: Quantitative Easing in Developed Countries

Table 7: Quantitative Easing announcements in the United States

Date	Decision	Other information
25 November 2008	Fed announces that it will buy $100 billion of GSE (Government-sponsored enterprise) debt and up to 500 billion in MBS (Mortgage-Backed Securities).	
1 December 2008	Ben Bernanke indicates that the Fed might purchase long-term treasury bonds	
16 December 2008	FOMC communiqué mentions the possibility of purchasing long-term Treasuries.	Fall in target Fed funds rate from 1% to a range between 0 and 0.25%.
28 January 2009	FOMC communiqué emphasizes the need to purchase agency debt and MBS. Purchases of long-term Treasuries also considered.	Launch of TALF funding facility (stands for Term Asset-Backed Securities Loan Facility).
18 March 2009	Fed announces that is going to acquire an extra $750 billion in MBS, $100 billion in agency debt and $300 billion in long-term Treasuries.	
21 September 2010	FOMC indicates that additional loosening of monetary policy may be needed to sustain growth.	
3 November 2010	FOMC launches a new long-term security purchasing programme called QE2, which consists of purchasing $600 billion in Treasury securities over November 2010-June 2011. FOMC reserves the right to revise purchasing frequencies and volumes if need be.	
9 August 2011	FOMC communiqué intimates the possible implementation of a new long-term security purchasing programme.	Fed commits to maintain key rates between 0 and 0.25% until mid-2013 at least.
21 September 2011	Fed launches "Twist operation" consisting of selling, by the end of June 2012, $400 billion of Treasury securities with remaining maturities of 3 years and less and buying and equal amount of Treasury securities with remaining maturities of 6 years to 30 years.	Key rates range between 0 and 0.25%.
20 June 2012	The FOMC decided to extend its "Twist operation" until late Decembre 2012. The Fed buys another $267 billion in T-Bonds, selling an equivalent amount of short-term securities, thereby leaving the size of its balance sheet unchanged.	
13 September 2012	The Fed announces a third quantitative easing programme (QE3) consisting of a monthly purchase of $40 billion in MBS and an ongoing purchase of market securities.	Discount rates are kept between 0 and 0.25%, until mid-2015 at least.

Source: C.J. Neely (2011) + updated by the authors

Table 8: Quantitative Easing announcements in the United Kingdom

Date	Decision	Other information
11 February 2009	February inflation report and ensuing press conference intimate possibility of security purchases.	
5 March 2009	Monetary Policy Committee (MPC) announces that it might purchase up to £75 billion in assets over the next quarter. These purchases would be funded by monetary creation involving an increase in commercial bank reserves. With respect to government securities, BoE purchases will only cover Gilts with a residual maturity of between 5and 25 years.	Intervention rates drop from 1% to 0.5%.
7 May 2009	MPC announces an increase in its asset purchases to £125 billion.	
6 August 2009	MPC announces an increase in its asset purchases to £175 billion.	

4 February 2010	Henceforth, the BoE can purchase Gilts with a residual maturity of more than three years. MPC announces that asset purchase volumes should be set at £200 billion.	MPC reserves the right to modify its asset purchase programmes

Table 8: Quantitative Easing announcements in the United Kingdom - continued

6 October 2011	MPC announces an increase in asset purchases to £275 billion. The new asset purchase programme will be implemented within four months.	The size of the Asset purchase programme could be revised upwards. Intervention rates are kept at 0.5%
9 February 2012	The MPC announces that it will raise its asset purchase ceiling from £275 billion to £325 billion.	
5 July 2012	The MPC announces that it will raise its asset purchase ceiling from £325 billion to £375 billion.	

Source: Joyce et al (2010) + updated by the authors

Table 9: Quantitative Easing announcements in Japan

Date	Decision	Other information
5 October 2010	BoJ Monetary Policy Committee announces creation of a ¥5 trillion fund intended to finance asset purchases (government bonds, commercial paper, corporate bonds).	BoJ lowers its intervention rates from a range of 0 to 0.1%, vs. 0.1% since December 2008.
23 October 2010	BoJ adopts a ¥5 trillion financial asset purchase programme broken down as follows: -purchase of ¥3.5 trillion yen in government bonds and treasury bills -purchase of ¥500 billion in commercial paper -purchase of ¥500 billion in corporate bonds -purchase of ¥500 billion in risky assets (property funds or mutual funds)	
14 March 2011	Following the Fukushima earthquake and tsunami, BoJ increases its asset purchase programme by ¥5 trillion, stating that this can be extended further if need be.	
4 August 2011	BoJ extends its asset purchase programme by ¥5 trillion. Total now amounts to ¥15 trillion.	
14 February 2012	The BoJ announces the purchase of a further ¥10 trillion in Treasury bonds before yearend 2012. This increases its asset purchase programme to a total of ¥ 65 trillion.	

Source : Authors

Appendix 2: Results of the VECM estimations

Table 10: United States -EUR/USD parity

	Δe_t	Δmb_t
z_{it-1}	**-0.143** **(-3.556)**	**0.077** **(1.343)**
Δ_{et-1}	0.364 (3.430)	-0.250 (-1.717)
Δ_{et-2}	-0.038 (-0.334)	-0.386 (-2.499)
Δ_{et-3}	0.368	0.232

	(3.167)	(1.450)
Δmb_{t-1}	0.021 (0.234)	0.829 (6.786)
Δmb_{t-2}	0.247 (2.362)	-0.406 (-2.826)

Table 10: United States -EUR/USD parity - continued

Δmb_{t-3}	-0.254 (-3.124)	0.111 (0.991)
α_i	0.0003 (0.105)	0.008 (2.000)

Table 11: United States –USD nominal effective exchange rate

	Δe_t	Δmb_t
z_{it-1}	**-0.167** **(-3.938)**	**-0.103** **(-1.188)**
Δe_{t-1}	0.151 (1.340)	0.398 (1.727)
Δe_{t-2}	0.152 (1.365)	0.452 (1.990)
Δe_{t-3}	0.155 (1.363)	-0.176 (-0.754)
Δe_{t-4}	0.315 (2.742)	-0.040 (-0.169)
Δmb_{t-1}	-0.007 (-0.113)	0.817 (6.450)
Δmb_{t-2}	-0.156 (-1.938)	-0.345 (-2.103)
Δmb_{t-3}	0.182 (2.312)	0.057 (0.354)
Δmb_{t-4}	0.025 (0.394)	0.053 (0.412)
α_i	-0.001 (-0.658)	0.009 (1.878

Table 12: United Kingdom –GBP/USD parity

	Δe_t	Δmb_t
z_{it-1}	**-0.242** **(-3.507)**	**-0.173** **(-1.058)**
Δe_{t-1}	0.197 (1.706)	0.806 (2.934)
Δe_{t-2}	0.083 (0.678)	-0.390 (-1.335)
Δe_{t-3}	0.469 (3.977)	0.541 (1.933)
Δe_{t-4}	0.179 (1.312)	-0.891 (-2.752)

Table 12: United Kingdom –GBP/USD parity - continued

Δmb_{t-1}	0.027 (0.557)	0.026 (0.233)
Δmb_{t-2}	-0.040 (-0.836)	0.171 (1.484)
Δmb_{t-3}	-0.012 (-0.255)	0.097 (0.857)
Δmb_{t-4}	-0.011	-0.089

	(-0.242)	(-0.803)
α_i	0.0009 (0.243)	0.015 (1.671)

Table 13: United Kingdom –GBP nominal effective rate

	Δe_t	Δmb_t
zi_{t-1}	**-0.122** **(-2.138)**	**-1.031** **(-4.579)**
Δe_{t-1}	0.343 (2.604)	1.245 (2.404)
Δe_{t-2}	0.158 (1.145)	1.625 (2.986)
Δe_{t-3}	0.249 (1.698)	0.362 (0.627)
Δmb_{t-1}	-0.019 (-0.694)	-0.163 (-1.485)
Δmb_{t-2}	-0.017 (-0.603)	0.126 (1.144)
Δmb_{t-3}	-0.036 (-1.275)	0.083 (0.749)
α_i	0.0006 (0.256)	0.028 (2.904)

Source: Authors