# Specific Features of the Velocity of Money for Euro and Non-Euro Countries across the Euro Entry

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Eleven European countries adopted the Euro as their single national currency in 1999, and others have followed suit to form a 19-member single-currency bloc by 2015. Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, Netherlands, Portugal, and Spain were the founding members. In the ordinary least squares (OLS)/panel regressions for 1992–2011 for seven Euro and four non-Euro countries, the GDP growth rate has a strong positive effect on the money velocity change rate, whereas the money growth rate exhibits a strong negative effect. Generally, deposit rates have strong positive effects and lending rates present negative effects for the seven Euro countries. In the regressions for the pre-Euro (1993–1997) and post-Euro (2003–2007) subperiods, we identify a shift in the importance of responsiveness of velocity change rate from money growth rates to inflation, deposit, and lending rates, although the impact of the former remains dominant. In the third nonlinear smooth transition regression (STR) models for the United Kingdom for 1980–2015 and the Netherlands for 1982–2015, we identify a much better fit than the aforementioned linear OLS models. We could also specify endogenously the structural break points in the behavior of money velocity against price level using STR models.

*Keywords*: Euro, Structural change, Smooth transition regression, Money demand, Velocity of money

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## I. Introduction

Danthine (2012, p. 2) emphasizes a noticeable increase in the ratio of domestic credit to GDP on a global scale from 74% in 1980 to approximately 138% in March 2009 and considers this extremely high level of indebtedness a key feature of the late global economic crisis. This significant increase implies a substantial decrease in the velocity of domestic credit by approximately 46% [=100 · (74 – 138)/138] over the time period.

Classical economists deny the dependence of money demand on interest rate and view money velocity as reasonably constant in the short run. Keynesians reckon that money demand critically depends on interest rate, and so does money velocity (Keynes 1936, pp. 197–201). Monetarists view money velocity as reasonably stable even in the long run (Friedman 1956, pp. 3–11). Friedman (1956, pp. 16–18) does not restrict money velocity to be constant but asserts that the primary determinant of money demand is the permanent income and that the velocity is fairly constant, considering the relative incentive of holding money to that of other assets will remain reasonably constant. Witnessing the sharp reduction in the M1 velocity in 1982 in the US following the 1979 monetary policy experiment, Friedman (1983, 1984) hypothesizes that increased money growth volatility causes decreased money velocity.

Hendry, and Ericsson (1991) evaluate the empirical model of the UK money demand developed by Friedman, and Schwartz (1982) and find misspecification that applies phase-average data in that model. Moreover, Hendry, and Ericsson (1991) propose a better-fitting, constant, dynamic error correction model using original annual data. They interpret the monetary model as a model of money but not of prices. Hendry, and Ericsson (1991, p. 23) also emphasize the importance of "a methodology of 'learning from the data' while being guided by economic theory in the interpretation of results … ." In response to Hendry, and Ericsson (1991), Friedman, and Schwartz (1991) emphasize the main focus of their previous study (Friedman, and Schwartz 1982) on the long-run money demand relationship abstracting from the intracyclical effects of Hendry, and Ericsson (1991) who "seek a single econometric specification that simultaneously describes cyclical and secular movements."

Ericsson, Hendry, and Prestwich (1998) extend the model of the UK money demand for 1878–1975 by Hendry, and Ericsson (1991) by updating data for 1976–1993. They account for changed data definitions of

money and highlight the effects of the financial deregulations on money demand arising from the 1971 Competition and Credit Control and the 1986 Building Societies Act. By considering the effects of the introduction of interest-bearing sight deposits, Ericsson, Hendry, and Prestwich (1998) obtain parameter constancy again as achieved by Hendry, and Ericsson (1991). Teräsvirta, and Eliasson (2001) evaluate the UK broad money demand by using a nonlinear error correction model. Their model variance dominates the model of Ericsson, Hendry, and Prestwich (1998), which is nonlinear in both variables and parameters.

Van Dijk *et al.* (2002) survey various smooth transition autoregressive models with two or more regimes. They also suggest modeling procedures from specification to forecasting with an application to the US unemployment rates. Saikkonen, and Choi (2004) study the smooth transition regression (STR) model with I(1) regressors and I(0) errors. They prove that the nonlinear least square estimator is consistent but inefficient when the regressors and errors are both serially and contemporaneously dependent. Saikkonen, and Choi (2004) also argue that a Gauss–Newton-type estimator based on regressions augmented by leads and lags can enhance efficiency. Choi, and Saikkonen (2004) develop test procedures that can be applied to assess the linearity of a cointegrating relation in the context of a nonlinear cointegrating STR model. They allow nonstationary I(1) regressors and both serial and contemporaneous correlations between the regressors and the error term. Furthermore, Choi, and Saikkonen (2004) apply their test procedures to the UK money demand from 1982 Q3 to 1998 Q4 and establish that the detrended real GDP and deposit rate are important candidates for transition variables.

Kang (2002) investigates the issues of identification and estimation under multiple cointegration relations. Kang (p. 33) emphasizes the role of irreducible cointegration relations "to show how multiple cointegration relations imply cointegration relations among certain subsets of time series." To capture the dynamic structure of the nonstationary behavior of an economic time series, Kim (2012) develops a nonparametric kernel estimation method for evolutionary autoregressive models with time-varying coefficients. Kim (2012) also assumes locally stationary processes adopting a local linear smoother to utilize the standard results of the stationary processes.

Bordo *et al.* (1997) emphasize the importance of the institutional role of the financial system in explaining the features of money velocity

over a long period of 1870–1985 for Canada, the US, the UK, Sweden, and Norway. They also support the transmission of financial changes across the five countries by identifying the cointegrating relationship of velocity, permanent income, interest rates, and institutional change proxy variables among the countries. Carlson *et al.* (2000) reexamine the usefulness of monetary aggregates in explaining the behavior of nominal economic activity, following the jump in M2 velocity in the early 1990s in the US. They ascertain that the aggregate money measures, particularly M2, maintain the predictive content for the nominal output once they control the effects of financial innovation in that period. Carlson *et al.* (2000, pp. 356–361) emphasize the main role of a massive reallocation in household portfolios from time deposits to mutual funds, especially bond funds. They consider the reduction in the transaction costs of mutual funds and the increased accessibility to households as major determinants for the reallocation and assert that the restructuring of the credit markets and financial innovation left only a one-time effect on M2 demand and a consequent upward shift of the velocity from around 1990 to 1994 in the US.

Carstensen (2006) tests the stability of M3 money demand in the European Monetary Union using data from 1980 Q1 to 2003 Q2. He finds that the excessive growth rate of M3 from the end of 2001 in the Euro area and the seemingly unstable money demand can be fully explained by the equity returns and stock market volatility. The reasoning is that investors substitute risky assets into safe assets, including funds that are part of M3, following the stock market downturn at the end of 2001. Carstensen (2006) employs the fully modified ordinary least squares (OLS) proposed by Phillips, and Hansen (1990) and the full-information maximum likelihood proposed by Johansen (1988, 1991) and shows that the parameters in the money demand function remained stable from the pre-EMU period of 1980 Q1–1988 Q4 to the extended period of 1980 Q1–2003 Q2; hence, no indication of excess liquidity has been observed after 2001, once the stock market developments have been controlled. Assenmacher-Wesche, and Gerlach (2007) derive a unit relationship between money growth and inflation at low frequencies when the impact of interest rate changes on money demand is controlled for in the Euro area, Japan, the UK, and the US by using quarterly data from 1970 Q1 to 2005 Q4. They (p. 536) define low frequency as cycles with a periodicity of more than 5.6 years. Assenmacher-Wesche, and Gerlach (2007, p. 538) also

mention the possibility of a substantial impact of financial innovation on money velocity in the US. They (p. 535) assert that, especially for the Euro area, money growth plays a role in inflation at low frequencies, output gap at higher frequencies, and the import price shocks capturing the influence of exchange rate changes and oil price shocks at even higher frequencies.

Mayhew (1995) conducts an interesting study on the changes of money velocity in England from 1300–1700 by gathering data on population, national income, money supply, and price level from various historical sources. He emphasizes the importance of recognizing the different behaviors of gold and silver currencies and the role of credit in economic transactions. Mayhew (1995, pp. 254–255) argues that "an increase in credit is more likely to be associated with a rise in $M$ than with a rise in $V$." Thus, the velocity $V$ will fall rather than rise in an expanding and commercializing economy. Muscatelli, and Spinelli (1997) investigate the stability of money demand in Italy by using annual data for 1861–1990. Moreover, they adopt an error correction model following cointegration tests. Muscatelli, and Spinelli (1997, pp. 59–60) ascertain that money demand has been stable for the entire period, including two periods of major policy and institutional changes, namely: 1) the interwar period when Mussolini announced a monetary stabilization in 1926 and Italy reentered the gold standard in 1927, and 2) the late 1970s when major financial innovation materialized with the issue of new type of government bonds.

In this study, we identify the main determinants of money velocity and any differences between Euro and non-Euro member countries. We also search for structural changes across the introduction of the single currency in the features of money velocity. The remainder of this paper is organized as follows. Section II describes the data for regression analysis for the 11 selected European countries taken from 1992–2011. Section III runs OLS regressions to identify the main determinants of money velocity. Section IV evaluates the structural differences between Euro and non-Euro member countries and the effects of the Euro adoption. Section V extends the model to nonlinear STRs for the UK as a non-Euro member for 1980–2015 and the Netherlands as a Euro member for 1982–2015 to estimate the time-varying relationships of money velocity with price level and to endogenously identify structural break points. Finally, Section VI concludes the study.

## II. Data Description

We mainly refer to the International Monetary Fund (IMF) International Financial Statistics (henceforth designated as *IFS*) of various issues for the data for the 11 European countries.[1] The names or definitions of some data series have been changed over the years and consequently these series exhibit several discontinuities. The major features of the IMF data are summarized in Appendix Table 1.

### *A. Selection of Variables*

Appendix Table 1 shows that the domestic credit (32) for money stock, the consumer price index (CPI) (64) for price index, and the GDP (99b or 99b.c) for output generally provide the most comprehensive data series for the countries.[2] Deposit and lending rates for the private sector would be more appropriate in finding the decisive factor of the money demand than government bond yield (61). *IFS* provides reasonably consistent data for deposit rates (60l) and lending rates (60p) for most countries in our study. Austria has missing data for deposit/lending rates for 2000–2002 and for lending rates for 1992–1997; hence, we use deposit rates for households with 1-year to 2-year maturity and loan rates for household consumption for 1996–2011 for new contracts from the Austrian National Bank (Oesterreichische Nationalbank; Available at http://www.oenb.at/en/). Most Euro member countries in our sample—Belgium, France, Germany, Italy, Netherlands, and Spain—have experienced transition from national currency deposit/lending rates to Euro rates from 2003 onward. Therefore, we use data for deposit rates (60l) and lending rates (60p) for these countries for 1992–2002 and deposit rates of new contracts for the household (60lhn) and lending rates of new contracts for the household (60pns) for 2003–2011.[3] Norway has missing data for deposit/lending rates for 2010–

[1] They are *IFS*2004 for 1992–1995, *IFS*2008 for 1996–1999, and *IFS*2012 for 2000–2011. We consider seven Euro countries and four non-Euro countries for our study. The seven Euro countries are Austria, Belgium, France, Germany, Italy, Netherlands, and Spain, and the four non-Euro countries are Norway, Sweden, Switzerland, and the United Kingdom as of October 2014.

[2] Numerical numbers with/without alphabetical suffixes within the parentheses are the specific codes of the corresponding series in the *IFS*.

[3] Although other deposit and lending rates for the nonfinancial corporations

2011; consequently, we use sight deposit rates and overnight lending rates for 1992–2011 from the Norges Bank (Available at http://www.norges-bank.no/en/Statistics/Interest-rates/). Sweden has missing data for deposit/lending rates for 2006 onward, and we thus obtain data for deposit/lending rates for banks from the Swedish central bank, the Riksbank (Available at http://www.riksbank.se), for 1994–2011. The UK also has missing data for deposit rates for 1999 onward; hence, we use data for lending rates (60p) from the IMF *IFS*, but we use time deposit rates (IUMWTTA) for 1995–2011 from the Bank of England (Available at http://www.bankofengland.co.uk/Pages/home.aspx).

Norway has missing data for domestic credit (32) for 2007–2011 from the IMF *IFS*. Hence, we acquire data for domestic credit (C1) for Norway from the Norwegian central bank (http://www.norges-bank.no) for the entire period of 1992–2011. The domestic credit for Sweden shows considerable unexplained changes in 1996 and 2001; thus, we use M3 data from the Swedish Central Bank website (Available at http://www.riksbank.se) for 1992–2006 linking M2 data from the IMF *IFS* for 2007–2011.[4]

Data for the Euro member countries show changes in currency denomination from national currency units to Euros around 1999.[5] Hence, we need to unify the currency units for the Euro member states. We opt to convert data in national currency units (from before the introduction of the Euro to the countries involved) into Euros.[6]

Having decided the reference data, we derive relevant variables for analysis. We calculate consumer price inflation rates by using CPI

and for the outstanding stocks are also available, general movement patterns are quite similar, and those two series (60 lhn and 60 pns) would suffice for our objective. Obviously, more detailed disaggregation between the household sector and the corporation sector in deposit and lending rates and the corresponding amounts of deposits and loans would provide a more refined analysis.

[4] For Sweden, M2 rather than M3 from the IMF *IFS* shows greater consistency with M3 from the Riksbank for the overlapping period of 1998–2006.

[5] Euro was introduced in 1999 only as an accounting medium, and actual circulation of paper money and coins began on 1 January 2002 at fixed conversion rates. Refer to https://www.ecb.europa.eu/euro/intro/html/index.en.html.

[6] Alternatively, we may convert data in Euro units from 1999 onward to national currency units, but the resulting change rates of nominal variables will remain the same and would not affect the analysis in this study.

(*CPI*), money growth rates by using domestic credit, money growth rate volatility by using money growth rates with five-period backward-moving sample standard deviation, and money velocity by dividing GDP by domestic credit. We also add unemployment rates (*UNEMP*) for an alternative regression model in later analysis.

*B. Stationarity Test*

Before we run regressions, we need to check the stationarity of the variables to avoid possible spurious regressions.[7] The results of panel unit root test are shown in Table 1.

## III. Regression Analysis

In this section III, we first run either pooled OLS or panel regressions for the Euro and non-Euro groups separately to identify the main causes for the changes in money velocity. For actual analysis, we employ original annual data rather than the phase-average data adopted by Friedman, and Schwartz (1982) because our sample period is only 20 years and the phase-average data would leave at most four to five phases, *i.e.*, too few data points, for any country for 1992–2011. We begin with the quantity theory of money Equation (1).[8]

$$MV = PY \tag{1}$$

where $M$ is the total quantity of money, $P$ is the average price per transaction, $V$ is the velocity of money, and $Y$ is the aggregate output. If we change this equation into the rate of changes form, we obtain $m + v = p + y$, where $m$ is the money growth rate, $v$ is the change rate of velocity, $p$ is the inflation rate, and $y$ is the income growth rate. Rearranging this equation for the velocity change, we get $v = p - m + y$. We add nominal interest rates $r$ (deposit and lending rates) in levels and construct the following regression equation to identify the effect of

[7] cf. Dougherty (2007, pp. 381–407) and Greene (2008, pp. 739–769) for a general reference to nonstationarity. ref. Baltagi (2008, pp. 273–287) for panel unit root tests.

[8] Mishkin (1998, p. 538). However, we should note the difference between $T$ and $Y$. See Cramer (1987, p. 801).

**TABLE 1**
RESULTS OF THE PANEL UNIT ROOT TEST

| Variables | Differencing | Seven Euro Countries | | Four Non-Euro Countries | |
|---|---|---|---|---|---|
| | | 1992–2011 | 1996–2011 | 1992–2011 | 1996–2011 |
| Velocity | Level | nonstationary | stationary[†] (nonstationary) | nonstationary | nonstationary |
| | 1st difference | stationary** | stationary** | stationary** | stationary** |
| Vel_CR | Level | stationary** | stationary** | stationary** | stationary** |
| | 1st difference | stationary** | stationary** | stationary** | stationary** |
| Deposit | Level | stationary**(*)[a] | stationary** | stationary** (stationary*)[a] [stationary**][b] | stationary** (nonstationary)[a] |
| | 1st difference | stationary** | stationary** | stationary** | stationary** |
| Lending | Level | stationary** | stationary** (stationary*)[a] [nonstationary][b] | stationary** (stationary*)[a] | stationary* (nonstationary)[a] |
| | 1st difference | stationary** | stationary** | stationary** | stationary** |
| DC | Level | nonstationary | nonstationary | nonstationary | nonstationary |
| | 1st difference | nonstationary [stationary**][b] | nonstationary [stationary**][b] | nonstationary | nonstationary |
| | 2nd difference | stationary** | stationary** | stationary** | stationary** |
| CPI | Level | nonstationary | nonstationary | nonstationary | nonstationary |
| | 1st difference | stationary** | stationary** | nonstationary (stationary*)[a] [stationary**][b] | stationary[†] (stationary*)[a] [stationary**][b] |
| | 2nd difference | stationary** | stationary** | stationary** | nonstationary (stationary**)[a] |
| PPI | Level | nonstationary | nonstationary | nonstationary | nonstationary |
| | 1st difference | stationary*(**)[a] | nonstationary [stationary**][b] | nonstationary [stationary*][b] | nonstationary [stationary*][b] |
| | 2nd difference | stationary** | stationary** | nonstationary (stationary**)[a] | nonstationary (stationary**)[a] |
| Inf_CPI | Level | stationary** | stationary** | stationary** | stationary** |
| | 1st difference | stationary** | stationary** | stationary** | stationary** |
| DC_GR | Level | stationary** | stationary* (stationary[†])[a] [stationary**][b] | stationary** (stationary**)[a] [stationary*][b] | stationary* |
| | 1st difference | stationary** | stationary** | stationary** | stationary** |

**TABLE 1**
(CONTINUED)

| Variables | Differencing | Seven Euro Countries | | Four Non-Euro Countries | |
|---|---|---|---|---|---|
| | | 1992–2011 | 1996–2011 | 1992–2011 | 1996–2011 |
| GDP_GR | Level | stationary** | stationary** | stationary** (stationary†)[a] [stationary**][b] | stationary** |
| | 1st difference | stationary** | stationary** | stationary** | stationary** |
| UNEMP | Level | stationary* (stationary*)[a] [nonstationary][b] | stationary** (stationary*)[a] [nonstationary][b] | stationary** (stationary*)[a] [nonstationary][b] | stationary* (stationary†)[a] [nonstationary][b] |
| | 1st difference | stationary** | stationary** | stationary** | stationary** (stationary**)[a] [stationary*][b] |
| MGR_Vol | Level | N/A[c] | stationary* (nonstationary)[a] | N/A[c] | nonstationary |
| | 1st difference | N/A[c] | stationary** | N/A[c] | stationary** |
| VOL_CR | Level | N/A[c] | stationary** | N/A[c] | stationary** |
| | 1st difference | N/A[c] | stationary** | N/A[c] | stationary** |

Note: ** indicates significance at 1% level, * at 5% level, and † at 10% level.

a: First asterisk marking shows the common unit root process (Levin, Lin, and Chu t) test results, and second notation within the parentheses shows the individual unit root process (Im, Pesaran, and Shin W-stat, ADF-Fisher chi-square, and PP-Fisher chi-square) test results. If two test procedures produce the same significance level, then we show only one common asterisk mark.

b: Second/third indication in the brackets shows the results of individual unit root process test by using PP-Fisher chi-square.

c: Not applicable.

interest rates on money demand, and therefore, on money velocity. We also selectively add the change rate of money growth rate volatility to test Friedman's (1983, 1984) hypothesis. We use change rates rather than level values because a few variables show nonstationarity, as presented in Table 1.

$$v_t = \alpha + \beta_1 dr_t + \beta_2 lr_t + \beta_3 p_t + \beta_4 y_t + \beta_5 m_t + \beta_6 vol\_cr_t + \varepsilon_t \tag{2}$$

where $v_t$ is the money velocity change rate, $dr_t$ is the deposit rate, $lr_t$ is the lending rate, $y_t$ is the GDP growth rate, $p_t$ is the CPI inflation rate,

$vol\_cr_t$ is the change rate of money growth rate volatility, and $\varepsilon_t$ is the disturbance term. Money growth rate volatility is calculated with a 5-year backward-moving sample standard deviation as follows:

$$MGR\_VOL_t = STDEV(DC\_GR_{t-4}, DC\_GR_{t-3}, DC\_GR_{t-2}, DC\_GR_{t-1}, DC\_GR_t) \quad (3)$$

where *STDEV* denotes the sample standard deviation. We show the regression results with the most appropriate panel fixed effects following *F*-tests for the regression Equation (2) for the seven Euro countries in Table 2 and for the four non-Euro countries in Table 3.[9] Given the inflation rate and money growth rate, velocity change rate and GDP growth rate would move in lockstep, *i.e.*, 1 to 1 with each other from the quantity Equation (1). Therefore, we rerun the regressions (EURO3) and (EURO4) with unemployment rate (*UNEMP*) instead of GDP growth rate (*GDP_GR*) and show the results as (EURO5) and (EURO6), respectively, to alleviate any potential swamping effect of the GDP growth rate on the velocity change rate coming from the identity condition. *UNEMP* is used as a proxy for *GDP_GR* in (EURO5) and (EURO6). This practice also applies to the non-Euro countries in Table 3. Overall, we run three sets of regressions for Equation (2), each for the Euro and non-Euro countries, alternatively without or with *VOL_CR*, namely: 1) with only *DEPOSIT*, *LENDING*, and *INF_CPI* as regressors, 2) adding *GDP_GR* and *DC_GR* to the first case, and 3) replacing *GDP_GR* with *UNEMP* in the second case.

The regression results in Table 2 show a substantial and significant positive effect of deposit rates and a smaller yet significant negative effect of lending rates in the models (EURO1) and (EURO2) for the seven Euro countries. These results are as expected because the deposit rates would work as an opportunity cost for holding money and lending rates would act as a negative opportunity cost. The high deposit rate accelerates the turnover rate of money. CPI inflation rates have a relatively sizeable and significant negative effect in (EURO1) and (EURO2). However, the effects of deposit, lending, and CPI inflation rates become muted when GDP and money growth rates are included in the regressions of (EURO3) and (EURO4). GDP growth rates have

[9] Details are available from the author upon request.

**Table 2**
Regression Results I (Seven Euro Countries)

| Dependent Variable: VEL_CR | | | | | | |
|---|---|---|---|---|---|---|
| | Seven Euro Countries | | | | | |
| Regressors | 1993–2011 | 1997–2011 | 1993–2011 | 1997–2011 | 1993–2011 | 1997–2011 |
| | (EURO1) | (EURO2) | (EURO3) | (EURO4) | (EURO5) | (EURO6) |
| DEPOSIT | 2.409047** | 2.750129** | −0.033352 | −0.014923 | 0.373943* | 0.430532† |
| | (0.0000) | (0.0007) | (0.1417) | (0.6563) | (0.0262) | (0.0708) |
| LENDING | −0.647144** | −0.664025** | 0.022286† | 0.033046* | −0.378744** | −0.394832** |
| | (0.0022) | (0.0027) | (0.0960) | (0.0343) | (0.0000) | (0.0002) |
| INF_CPI | −1.094618* | −1.565096* | 0.006032 | 0.003217 | 1.029676** | 1.027558** |
| | (0.0436) | (0.0189) | (0.8426) | (0.9258) | (0.0000) | (0.0000) |
| GDP_GR | - | - | 0.961565** | 0.971949** | - | - |
| | | | (0.0000) | (0.0000) | | |
| DC_GR | - | - | −0.911893** | −0.914232** | −0.718544** | −0.712841** |
| | | | (0.0000) | (0.0000) | (0.0000) | (0.0000) |
| UNEMP | | | | | 0.022570 | 0.009420 |
| | | | | | (0.6075) | (0.8631) |
| VOL_CR | - | 0.000152 | - | 0.000843* | - | 0.001187 |
| | | (0.9685) | | (0.0114) | | (0.6172) |
| Constant | −1.848344 | −1.342692 | −0.171728† | −0.315430* | 1.800707** | 1.787469† |
| | (0.3392) | (0.6322) | (0.0566) | (0.0172) | (0.0091) | (0.0896) |
| Panel | cross-section fixed + period fixed | cross-section fixed + period fixed | none | none | none | none |
| $R^2$ | 0.557839 | 0.635148 | 0.996130 | 0.996227 | 0.796604 | 0.805482 |
| $\bar{R}^2$ | 0.440797 | 0.525692 | 0.995974 | 0.995996 | 0.788403 | 0.793572 |
| N | 7 | 7 | 7 | 7 | 7 | 7 |
| T | 19 | 15 | 19 | 15 | 19 | 15 |

Note: Figures in parentheses are *p*-values. ** denotes significance at 1% level, * at 5% level, and † at 10% level. Data for 1992 in (EURO1), (EURO3), and (EURO5) are lost due to the calculation of velocity change rate. Data for 1992–1996 in (EURO2), (EURO4), and (EURO6) are lost due to the calculation of VOL_CR using a 5-year backward-moving standard deviation.

nearly 1 to 1, strong and significant positive effect, and money growth rates also show a strong, close to 1 to 1, and significant negative effect on the velocity change rate both in (EURO3) and (EURO4). These results confirm the potential swamping effect mentioned above, which reflects

**TABLE 3**
REGRESSION RESULTS II (FOUR NON-EURO COUNTRIES)

| | Dependent Variable: VEL_CR | | | | | |
|---|---|---|---|---|---|---|
| | Four Non-Euro Countries | | | | | |
| Regressors | 1993–2011 | 1997–2011 | 1993–2011 | 1997–2011 | 1993–2011 | 1997–2011 |
| | (NE1) | (NE2) | (NE3) | (NE4) | (NE5) | (NE6) |
| DEPOSIT | 0.653835<br>(0.2569) | 0.034157<br>(0.9598) | 0.073454*<br>(0.0384) | 0.018261<br>(0.6469) | −0.175548<br>(0.7683) | −0.625074<br>(0.3926) |
| LENDING | −0.978533<br>(0.1478) | −0.692129<br>(0.3181) | −0.035997<br>(0.2110) | −0.028950<br>(0.4265) | 0.458322<br>(0.3465) | 0.251759<br>(0.7079) |
| INF_CPI | −0.287044<br>(0.5695) | 0.035137<br>(0.9511) | 0.024152<br>(0.3094) | −0.011330<br>(0.6818) | 0.385372<br>(0.3395) | 0.104713<br>(0.8346) |
| GDP_GR | - | - | 0.927801**<br>(0.0000) | 0.899843**<br>(0.0000) | - | - |
| DC_GR | - | - | −0.913459**<br>(0.0000) | −0.914602**<br>(0.0000) | −0.716855**<br>(0.0000) | −0.865893**<br>(0.0000) |
| UNEMP | - | - | - | - | 0.000383<br>(0.9990) | −0.143494<br>(0.7735) |
| VOL_CR | - | 0.007543<br>(0.6251) | - | 0.000181<br>(0.7791) | - | 0.007885<br>(0.5537) |
| Constant | 1.791050<br>(0.4072) | 0.714288<br>(0.7253) | −0.074634<br>(0.3667) | 0.219553†<br>(0.0645) | 0.767885<br>(0.7277) | 4.819789<br>(0.1341) |
| Panel | period fixed | period fixed | cross-section fixed | cross-section fixed + period fixed | cross-section fixed | cross-section fixed + period fixed |
| $R^2$ | 0.472069 | 0.518154 | 0.998317 | 0.999279 | 0.508414 | 0.765809 |
| $\bar{R}^2$ | 0.262889 | 0.306612 | 0.998113 | 0.998819 | 0.448828 | 0.616188 |
| N | 4 | 4 | 4 | 4 | 4 | 4 |
| T | 19 | 15 | 19 | 15 | 19 | 15 |

Note: Figures in parentheses are *p*-values. ** denotes significance at 1% level, * at 5% level, and † at 10% level. Data for 1992 in (NE1), (NE3), and (NE5) are lost due to the calculation of velocity change rate. Data for 1992–1996 in (NE2), (NE4), and (NE6) are lost due to the calculation of VOL_CR using a 5-year backward-moving standard deviation.

the identity relation of the quantity theory of money Equation (1). In the alternative regressions (EURO5) and (EURO6), the positive effect of deposit rates and the strong negative effect of lending rates on velocity change rate are preserved, although with a much smaller size. *DC_GR*

in (EURO5) and (EURO6) still displays a strong negative effect on *VEL_CR*, although slightly smaller in size than that in (EURO3) and (EURO4). Furthermore, in (EURO5) and (EURO6), CPI inflation rates show a strong positive effect on velocity change rate in contrast to the negative effect in (EURO1) and (EURO2). However, unemployment rate shows no significant effect on *VEL_CR*. Likewise, the volatility change rate in (EURO6) does not have any significant effect on the velocity change rate.

In Table 3, for the four non-Euro countries, deposit, lending, or CPI inflation rates do not have any significant effects on the money velocity change rates, except *DEPOSIT* in (NE3). GDP and money growth rates have similar effects on *VEL_CR* in (NE3) and (NE4) like ones for the Euro countries. In (NE5) and (NE6) with unemployment rate in place of *GDP_GR*, all of the variables other than *DC_GR* have no significant effect on the velocity change rate, in which *DC_GR* keeps a substantial and significant negative effect on *VEL_CR*, again smaller in size than that in (NE3) and (NE4).

Tables 2 and 3 indicate that the change rates of money growth rate volatility *VOL_CR* do not have any significant effect on *VEL_CR*, except in model (EURO4), in which *VOL_CR* has a significant positive but negligibly small (0.000843) effect on the velocity change rate. Hence, our study does not support Friedman's (1983, 1984) hypothesis about the effect of money growth rate volatility on money velocity.

## IV. Structural Changes across the Euro Entry

We check whether any structural differences exist before and after the Euro introduction and between the Euro and non-Euro countries. Reflecting the initial regression results in Tables 2 and 3, we narrow down the set of explanatory variables to deposit/lending rates, CPI inflation rates, domestic credit change rates, and unemployment rates, dropping the GDP growth rates and the change rates of money growth rate volatility. We run the following regression model:

$$v_t = \mu + \delta_1 dr_t + \delta_2 lr_t + \delta_3 p_t + \delta_4 u_t + \delta_5 m_t + \eta_t, \tag{4}$$

where $u_t$ is the unemployment rate, $\eta_t$ is the disturbance term, and the other variables are the same as in Equation (2). We divide the entire period into 1) pre-Euro period for 1993–1997 and 2) post-Euro period

**TABLE 4**
REGRESSION RESULTS III (PRE- AND POST-EURO PERIODS)

| Dependent Variable: VEL_CR | | | | |
|---|---|---|---|---|
| | Seven Euro Countries | | Four Non-Euro Countries | |
| Regressors | 1993–1997 | 2003–2007 | 1993–1997 | 2003–2007 |
| | (EURO7) | (EURO8) | (NE7) | (NE8) |
| DEPOSIT | −0.401895 | 0.884559** | 1.628379† | 0.152640 |
| | (0.2990) | (0.0053) | (0.0811) | (0.7743) |
| LENDING | 0.945252* | −0.095905 | −1.568596 | −4.053353** |
| | (0.0385) | (0.4464) | (0.3159) | (0.0003) |
| INF_CPI | 1.251842* | 1.586171** | 1.639980† | 2.991426** |
| | (0.0118) | (0.0005) | (0.0826) | (0.0003) |
| DC_GR | −0.962893** | −0.788130** | −0.900181** | −0.779890** |
| | (0.0000) | (0.0000) | (0.0006) | (0.0007) |
| UNEMP | −0.864859* | 0.000111 | 0.207124 | −0.628896 |
| | (0.0326) | (0.9994) | (0.4852) | (0.1240) |
| Constant | 5.245523 | −1.418229 | 4.046652 | 18.59616** |
| | (0.3263) | (0.4726) | (0.4961) | (0.0001) |
| Panel | cross-section fixed + period fixed | none | period fixed | cross-section fixed + period fixed |
| $R^2$ | 0.941585 | 0.957778 | 0.834819 | 0.980125 |
| $\bar{R}^2$ | 0.886821 | 0.950499 | 0.669637 | 0.946055 |
| N | 7 | 7 | 4 | 4 |
| T | 5 | 5 | 5 | 5 |

Note: Figures in parentheses are *p*-values. ** denotes significance at 1% level, * at 5% level, and † at 10% level.

for 2003–2007 to avoid any probable abnormal impacts of the Euro transient period of 1998–2002 and the lingering global economic crisis accelerated by the Lehman Brothers bankruptcy in September 2008. Table 4 shows the regression results for Equation (4) for the seven Euro countries and for the four non-Euro countries.

Several specific features are observed in Table 4. Money deposit rates have a strong positive effect on velocity change rate during the post-Euro period for the seven Euro countries, and they exhibit a large but weak positive effect during the pre-Euro period for the four non-Euro countries. Lending rates have a positive effect on *VEL_CR* during the

| | Pre-Euro Period (1993–1997) | | Post-Euro Period (2003–2007) |
|---|---|---|---|
| Seven Euro Countries | LENDING (0.945*)<br>INF_CPI (1.252*)<br>DC_GR (−0.963**)<br>UNEMP (-0.865*) | → | DEPOSIT (0.885**)<br>INF_CPI (1.586**)<br>DC_GR (−0.788**) |
| Four Non-Euro Countries | DEPOSIT (1.628†)<br>INF_CPI (1.640†)<br>DC_GR (−0.900**) | → | LENDING (−4.053**)<br>INF_CPI (2.991**)<br>DC_GR (−0.780**) |

**Figure 1**
Structural Changes across the Euro Entry[10]

pre-Euro period for the Euro countries against conventional wisdom, but shows substantial and strong negative effect during the post-Euro period for the non-Euro countries. CPI inflation rates have a large and reasonably strong positive effect on *VEL_CR* during both periods and for both groups. The absolute size of the effects of domestic credit change rate on *VEL_CR* has been reduced by approximately 13% to 18% from the pre-Euro period to the post-Euro period for the two groups. The key feature here is that the market response in terms of money velocity change rate (*VEL_CR*) has become generally more sensitive to deposit, lending, and CPI inflation rates than to money growth rates (*DC_GR*) after the introduction of the single-currency Euro in both Euro and non-Euro countries. This outcome is understandable given the close link in trade and capital movements and the geographic proximity between the two groups. Unemployment rate has a negative and significant effect on *VEL_CR* only during the pre-Euro period and only for the seven Euro countries. The negative sign on *UNEMP* in (EURO7) is correct, considering we may expect the unemployment rates to move contrary to the GDP growth rates. We summarize as a diagram in Figure 1 the structural changes focusing on the significant variables in the money velocity change rate of Table 4.

[10] Figures inside parentheses show the coefficient estimates of the corresponding regressors, with the asterisks having the same significance level as in Table 4.

## V. STR of Money Velocity

Thus far, we have performed linear regressions for the seven Euro countries and four non-Euro countries across the Euro entry. The introduction of the single-currency Euro from 1999 into 11 European countries in the 20-member European Union at that time may have affected the money demand and consequently the money velocity not only in the Euro member countries but also in the neighboring non-Euro European countries. Changing the regression approach from the previous section, we now apply nonlinear regression methods to money velocity for the UK in the non-Euro group and the Netherlands in the Euro group for longer periods.[11]

We adopt the STR technique for the nonlinear model. This method has two particular merits over the linear model. First, the STR model can accommodate time-varying coefficients for the transition variables. The transitions of the slope coefficients or constant term themselves are "smooth," as implied by the name. Thus, the STR model may produce a better fit, especially around the transient region, than a linear OLS or step pattern of coefficients. Second, the transition point in the STR model is endogenously determined via the maximum likelihood approach given actual data. Hence, we can avoid somewhat arbitrary choice of structural breaks as we have chosen the Euro entry period as a break point in the previous section. The adoption of an STR model itself is heuristic, and we thus need to be cautious in interpreting the regression results. Visual checking of the actual regression outcome and scatter plots may help in this aspect.

We consider the STR model as

$$y_t = \mu + \omega\, g\left(z_{st}\right) + \alpha'\, x_t + \beta'\, x_t\, g\left(z_{st}\right) + \eta_t \tag{5}$$

[11] The selection of the United Kingdom and the Netherlands purely depends on data availability and technical issues in the STR regressions. Practical STR results critically depend on the initial values for the maximum likelihood iterations. We have also tried France and Germany as a sample for the Euro countries with various initial conditions using E-Views, but we could not obtain a proper regression result in the smooth transition regressions. STRs for France and Germany consistently produce singular covariance errors and thus show coefficients estimates but not the standard errors.

where $x_t = [x_{1t}, \ldots, x_{pt}]'$ is a $p$-dimensional $I(1)$ process, $\eta_t$ is a white noise, and

$$z_{st} = \gamma\left(x_{st} - c\right),\ \gamma \neq 0, \quad s \in \{1, \ldots, p\}. \tag{6}$$

$g(z_{st})$ is a smooth transition function of the process $x_{st}$ and the scalar parameters $\gamma$ and $c$. Among the other parameters in Equation (5), $\mu$ and $\omega$ are scalars, and $\alpha$ and $\beta$ are $p \times 1$ vectors of constants. We adopt a logistic function for $g(z_{st})$ with a single-transition variable ($p = 1$) and two regimes. We take the CPI (alternatively, the GDP deflator) as the transition variable reflecting the features in Figure 1.

$$g\left(z_{st}\right) = \frac{1}{1 + e^{-\gamma\left(x_{st} - c\right)}} \tag{7}$$

The coefficient for $x_t$ moves slowly between $\alpha$ and $\alpha + \beta$, and so does the intercept term between $\mu$ and $\mu + \omega$, as the value of $x_t$ changes. Replacing $y_t$ with $V_t$ and $x_{st}$ with $P_t$, regression Equation (5) transforms as follows:

$$V_t = \mu + \frac{\omega}{1 + e^{-\gamma\left(P_t - c\right)}} + \left[\alpha + \frac{\beta}{1 + e^{-\gamma\left(P_t - c\right)}}\right] P_t + \eta_t \tag{8}$$

where $V_t$ is the money velocity, and $P_t$ is the CPI (or GDP deflator).

We estimate the scale and location parameters $\gamma$ and $c$ alongside the coefficients $\alpha$, $\beta$, $\mu$, and $\omega$ in Equation (8) using maximum likelihood for the UK and the Netherlands. If $\gamma$ is nonzero, $c$ is finite, and $\beta$ is nonzero, then we may conclude that the price index *CPI* has a differential effect on money velocity depending on the values of *CPI* itself. For example, if $\gamma > 0$, $c > 0$, $\alpha < 0$, and $\beta > 0$, then *CPI* is considered to have a weaker negative effect on the velocity when the CPI is higher. Similarly, if $\gamma < 0$, $c > 0$, and $\omega > 0$, then the velocity level will be higher under lower CPI regime, controlling the effect of the CPI itself. The former turns out to be the Dutch case and the latter to be the British. Money velocity $V_t$ is defined as nominal GDP divided by monetary aggregates. We perform augmented Dickey–Fuller unit root tests for the relevant variables and show the results in Table 5.

We choose from Table 5 for regressions *GDP_DEF*, *INF_CPI*, *GDP_NC*, and *M*4_3*C* for the UK and *CPI*, *INF_CPI*, *GDP_NC*, and *M*3_*C* for the

**TABLE 5**
AUGMENTED DICKEY–FULLER UNIT ROOT TEST RESULTS (UK AND NETHERLANDS)

| Variables | Differencing | UK | Netherlands |
|---|---|---|---|
| | | 1980–2015 | 1982–2015 |
| CPI[a] | Level | nonstationary | nonstationary |
| [Index] | 1st difference | nonstationary | stationary* |
| | 2nd difference | stationary** | stationary** |
| GDP_DEF[a] | Level | nonstationary | nonstationary |
| [Index] | 1st difference | stationary* | stationary** |
| | 2nd difference | stationary** | stationary** |
| INF_CPI[b] | Level | stationary** | stationary** |
| [%pa] | 1st difference | stationary** | stationary** |
| | 2nd difference | stationary** | stationary** |
| INF[c] | Level | stationary* | stationary** |
| [%pa] | 1st difference | nonstationary | stationary** |
| | 2nd difference | stationary** | stationary** |
| GDP_NC[a] | Level | nonstationary | nonstationary |
| [bil.GBP/Euro] | 1st difference | stationary** | stationary* |
| | 2nd difference | stationary** | stationary** |
| M3_C[d] | Level | - | nonstationary |
| [mil. Euros] | 1st difference | - | stationary† |
| | 2nd difference | - | stationary** |
| M4_3C[e] | Level | nonstationary | - |
| [mil.GBP] | 1st difference | stationary† | - |
| | 2nd difference | stationary** | - |
| VEL[f] | Level | nonstationary | nonstationary |
| | 1st difference | stationary** | stationary** |
| | 2nd difference | stationary** | stationary** |

Note: ** indicates significance at 1% level, * at 5% level, and † at 10% level.

a: IMF *IFS*, http://www.imf.org/external/index.htm.

b: INF_CPI = [log(CPI) − log(CPI(−1))]*100.

c: INF = [log(GDP_DEF) − log(GDP_DEF(−1))]*100.

d: De Nederlandsche Bank, http://www.dnb.nl/en/home/index.jsp, Table 5.4 Contribution of the Netherlands to the Euro area monetary aggregates (stocks), M3 including currency in circulation.

e: Bank of England, http://www.bankofengland.co.uk/Pages/home.aspx. Three centuries of macroeconomic data.

f: VEL = Nominal GDP/M4_3C(M3_C).

Netherlands considering the data availability and stationarity.

*A. UK (1980–2015): Non-Euro Member*

The STR regression result for the UK of Equation (8) is obtained as in Equation (9).[12] All the *p*-values for the coefficients are zero to the fourth decimal place, except for the scale parameter $c(3) = \gamma$, for which *p*-value equals 0.0261. The STR regression line is shown as a solid curve along with the scatter plot in Figure 2. The STR regression curve implies that the money velocity in the UK responds to the GDP deflator negatively for the entire period. The responsiveness of the money velocity of the UK to GDP deflator became weak, as can also be observed in the combined coefficient within the bracket on *GDP_DEF* in Equation (9) when the GDP deflator increased above 58.077, which covers the period from 1990 onward. This time period coincides with that when the UK pegged its currency to the German Mark and was shortly to break away from the exchange rate mechanism in 1992.[13]

$$VEL_t = 2.427 + \frac{0.959}{1+e^{0.504(GDP\_DEF_t - 58.077)}} + \left[-0.016 + \frac{-0.021}{1+e^{0.504(GDP\_DEF_t - 58.077)}}\right] \bullet GDP\_DEF_t \quad \text{(STR; UK) (9)}$$

We have a caveat here. Although the apparent transition variable in Equation (9) is the GDP deflator, it may merely be a superficial proxy for more fundamental changes in money demand around 1990 in the UK. As indicated by the data, money velocity is generally falling with a couple of reversions in the trend, whereas the GDP deflator is continually rising without any reversion over the period. Therefore, we would need further search for the true causes in the future to take a proper account of this issue.

The OLS regression result of *VEL* on *GDP_DEF* is given as in Equation (10), with White heteroscedasticity-consistent standard errors

[12] We have also run the STR models with the inflation rates (*INF* or *INF_CPI*), government bond rates (*GBR*), deposit rates, or lending rates instead of *GDP_DEF* but could not acquire any significant estimates. This insignificant outcome is the same for the Netherlands below.

[13] Mishkin (2016, p. 516).

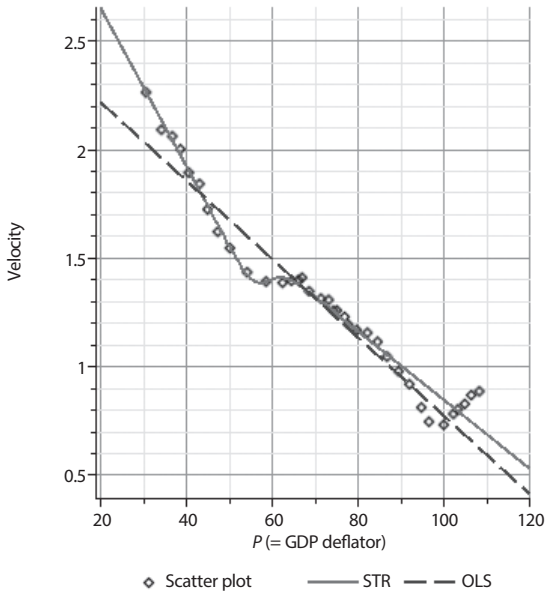


**FIGURE 2**
STR AND OLS REGRESSION LINES OF VELOCITY AGAINST GDP DEFLATOR WITH SCATTER PLOTS (UK, 1980–2015)

in the parentheses below the coefficients. The OLS regression line is superimposed as a dashed line in Figure 2. Figure 2 shows that the solid nonlinear STR regression line gives a much better fit than the linear OLS regression line.

$$VEL_t = \underset{(0.075)^{**}}{2.573} - \underset{(0.001)^{**}}{0.018} \bullet GDP\_DEF_t \qquad \text{(OLS; UK) (10)}$$

*B. Netherlands (1982–2015): Euro Member*

We run the same regressions for the Netherlands, as an example of a Euro country, for 1982–2015. The resulting STR and OLS regression results are given as Equations (11) and (12), respectively, and are shown in Figure 3 together with the scatter plot. Equation (11) presents that although the signs of $c(2) = \omega$, $c(3) = \gamma$, and $c(6) = \beta$ for the Netherlands are opposite to the ones for the UK, the direction of the effect of the price level *CPI* on the money velocity here is the same as the one of the

*GDP deflator* in the UK case. In other words, the reaction of the Dutch money velocity to *CPI* is also negative, similar to the reaction of the British one to *GDP deflator*. Moreover, at the level of *CPI* higher than 68.539, the slope of the *CPI* variable, and the term inside the brackets in Equation (11), becomes flatter, *i.e.*, less negative. The constant term, the first two terms in Equation (11) that are combined, becomes less positive when *CPI* exceeds the critical level of 68.539, which covers the period of 1992 onward in the Netherlands. However, this time period does not coincide with the Netherlands' adoption of the single-currency Euro in 1999. The value of *CPI* was 68.55 in 1992 and 80.05 in 1999 with base year 2010 in the Netherlands. Hence, we may assume that the weakening reaction of the money velocity to *CPI* has been caused by reasons other than the introduction of the Euro in the Netherlands.

$$VEL_t = 5.197 + \frac{-2.485}{1+e^{-0.658\,(CPI_t - 68.539)}} + \left[-0.058 + \frac{0.040}{1+e^{-0.658\,(CPI_t - 68.539)}}\right] \bullet CPI_t \quad \text{(STR; Netherlands) (11)}$$

$$VEL_t = \underset{(0.085)^{**}}{2.705} - \underset{(0.001)^{**}}{0.018} \bullet CPI_t \quad \text{(OLS; Netherlands) (12)}$$

As before, the OLS regression result of *VEL* on *CPI* is given as in Equation (12) for the Netherlands. The Dutch OLS regression line is superimposed as a dashed line in Figure 3. Again, for the Netherlands in the Euro bloc, we observe a better fit of the solid nonlinear STR regression line than the linear OLS regression line, especially around the transition region of *CPI* = 68.539.

## VI. Conclusion

In this study, with recent data for the 11 selected European countries from the IMF *IFS*, we have run three sets of regressions, namely: 1) OLS with the change rate of money velocity as a dependent variable and deposit/lending rates, CPI inflation rate, money growth rate, GDP growth rate, and change rate of money growth rate volatility as regressors for the period of 1992–2011; 2) OLS with the same dependent variable and regressors replacing GDP growth rate with unemployment

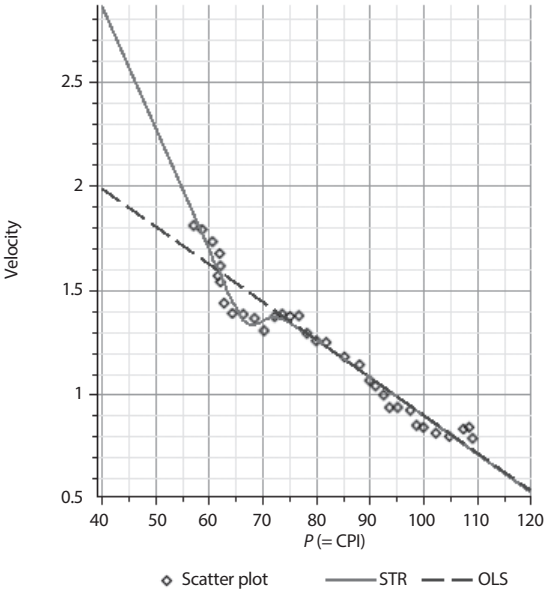


**FIGURE 3**
STR AND OLS REGRESSION LINES OF VELOCITY AGAINST CPI WITH SCATTER PLOTS (NETHERLANDS, 1982–2015)

rate and dropping the insignificant volatility change rate for the pre-Euro period of 1993–1997 and the post-Euro period of 2003–2007 separately; and 3) nonlinear STR with the money velocity as dependent variable and the price index, either *CPI* or *GDP deflator*, as a transition variable for the UK for 1980–2015 and the Netherlands for 1982–2015. We have selectively adopted appropriate panel regressions with fixed effects in the first two sets of regressions.

In the first set of regressions for Equation (2), we obtain the following results. First, for the Euro countries, deposit rates have a reasonably strong positive effect on money velocity change rate, whereas lending rates have a strong negative effect, except when both GDP and money growth rates are included in the regression. Conversely, for the non-Euro countries, deposit rates or lending rates do not have any siginificant effect on the change rate of money velocity (*VEL_CR*), except for the small positive effect of deposit rates in model (NE3). Second, for the Euro countries, CPI inflation rate (*INF_CPI*) has a large negative effect on *VEL_CR* when GDP growth rates (*GDP_GR*) or

money growth rates (*DC_GR*) are absent, but a substantial positive effect when both unemployment rate (*UNEMP*) and *DC_GR* are present in the model. *INF_CPI* does not have any significant effect on *VEL_CR* when both *GDP_GR* and *DC_GR* are present. By contrast, for the non-Euro countries, *INF_CPI* does not have any significant effect on *VEL_CR* in any model specification. Third, money growth rate (*DC_GR*) has a strong and significant negative effect on *VEL_CR* in all models for both groups, whereas GDP growth rate (*GDP_GR*) has a strong and significant positive effect. Fourth, unemployment rate has no significant effect. Fifth, the change rate of money growth rate volatility (*VOL_CR*) has a significant positive, but negligible small effect on *VEL_CR* only in one model where both *GDP_GR* and *DC_GR* are present and only for the Euro countries. Therefore, we may not support the arguments of Friedman's (1983, 1984) hypothesis about the effect of money growth rate volatility on money velocity.

In the second set of regressions with unemployment rates in place of GDP growth rates and without *VOL_CR* for the two subperiods before and after the introduction of Euro, we also obtain several interesting results. First, the most prominent feature is that the responsiveness of *VEL_CR* has become generally more sensitive to deposit/lending rates and CPI inflation rates compared with its responsiveness to money growth rates after the introduction of the single-currency Euro for both Euro and non-Euro countries. Second, unemployment rate does not have a significant effect on *VEL_CR*, except during the pre-Euro period only and only for the Euro countries, in which the sign is negative.

In the third set of STRs, we obtain better-fitting nonlinear regression curves than the linear OLS regression lines, especially around the transition regions. First, the STR models for the UK and the Netherlands produce highly significant estimation results. Second, the "linear" coefficients $c(1) = \mu > 0$ and $c(5) = \alpha < 0$ and the location parameter $c(4) = c > 0$ all share the same sign between the two countries. Third, the "nonlinear" coefficients $c(2) = \omega > 0$ and $c(6) = \beta < 0$ and the scale parameter $c(3) = \gamma < 0$ show opposite signs between the two countries.[14] Overall, *CPI* (alternatively, *GDP_DEF*) has a negative effect on *VEL* in both countries. Furthermore, notwithstanding the different signs of the coefficients, the level of the price index has the same differential effect

[14] The signs specified here denote the UK case.

on *VEL* in the sense that a high *CPI* (alternatively, *GDP_DEF*) leads to a weak impact of the *CPI* (alternatively, *GDP_DEF*) on *VEL*. The slope of the STR regression curve becomes flatter or less negative at higher levels of *CPI* (alternatively, *GDP_DEF*) above certain transition regions in both countries. In other words, the two countries show the same pattern of a regime shift (from more sensitive to less sensitive) in the reaction of velocity to the price level.

This paper also has some limitations. First, we did not investigate the impact of financial innovations on money velocity unlike numerous studies which highlighted such impact. Although we suppose that the period covered in this study did not experience noticeable changes in financial practices or regulations in the countries of concern, this issue may require further consideration. Second, only 11 countries were studied, and the period covered in the first two sets of panel regressions is as relatively short as 15 years. We may extend the study to a wider range of economies and longer time periods to obtain a deeper intuition on the subject. Third, we only considered the price index as a transition variable in the STR model. We may also evaluate the time-varying responsiveness of money velocity to other monetary variables, although we have not obtained any meaningful estimation results when we replaced the price index with inflation rates, government bond rates, deposit rates, or lending rates. Fourth, the transition period in the STR models, as indicated by the location parameter $c(4) = c > 0$ in Equations (9) and (11), occurred around 1990 for the UK and 1992 for the Netherlands unlike the assumed break points of 1999–2002 in Section IV. Hence, we may need to identify other causes for these structural changes than the introduction of the Euro.

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## APPENDIX

**Appendix Table 1**
IMF *IFS* Data Description

| No. | Country | Exchange Rate [P/A][a] | Money Stock [EoP][b] | Interest Rate | Price Index [P/A] | Output/ Unemployment Rate |
|---|---|---|---|---|---|---|
| 1 | Austria (Euro)[c] | (rf)[d] 1992–1998[e]: Schillings per USD 1999–2011[e]: Euros per USD | 1992–1999: Domestic Credit (32)[d] 2000–2011: Domestic Claims (32) 1998: missing | Deposit Rates: 1992–1999 (60l)[d], 2003–2011 (60lhn) Lending Rates: 1998–1999 (60p)[d] 2003–2011 (60pns) from www.oenb.at | Wholesale Prices (63)[d] CPI (64)[d] | GDP (99b)[d, f] 1992–1998: bil. Schillings 1999–2011: bil. Euros Unemployment Rate (67r)[d] |
| 2 | Belgium (Euro) | (rf) 1992–1998: Francs per USD 1999–2011: Euros per USD | 1992–1999: Domestic Credit (32) 2000–2011: Domestic Claims (32) 1998: missing | Deposit Rates: 1992–2002 (60l)[d], 2003–2011 (60lhn) Lending Rates: 1992–2002 (60p)[d] 2003–2011 (60pns) | Producer Prices: Home and Import Goods (63) CPI (64) | GDP (99b) 1992–1998: bil. Francs 1999–2011: bil. Euros Unemployment Rate (67r)[d] |
| 3 | France (Euro) | (rf) 1992–1998: Francs per USD 1999–2011: Euros per USD | 1992–1999: Domestic Credit (32) 2000–2011: Domestic Claims (32) 1998: missing | Deposit Rates: 1992–2002 (60l)[d], 2003–2011 (60lhn) Lending Rates: 1992–2002 (60p)[d] 2003–2011 (60pns) | 1992–2011: Producer Prices: Intermediate Indust. Goods (63a, –1999) 2000–2011: Producer Prices (63) CPI (64) | GDP (99b.c) 1991–1998: bil. Francs 1999–2011: bil. Euros Unemployment Rate (67r)[d] |
| 4 | Germany (Euro) | (rf) 1992–1998: Deutsche Mark per USD 1999–2011: Euros per USD | 1992–1999: Domestic Credit (32) 2000–2011: Domestic Claims (32) 1992–1998: bil. Deutsche Mark 1999–2011: bil. Euros | Deposit Rates: 1992–2002 (60l)[d], 2003–2011 (60lhn) Lending Rates: 1992–2002 (60p)[d] 2003–2011 (60pns) | PPI (63) CPI (64) | GDP (99b.c) 1991–1998: bil. Deutsche Mark 1999–2011: bil. Euros Unemployment Rate (67r)[d]: 1993–2011 |
| 5 | Italy (Euro) | (rf) 1992–1998: Lire per USD 1999–2011: Euros per USD | 1992–1999: Domestic Credit (32) 2000–2011: Domestic Claims (32) 1992–1998: tril. Lire 1999–2011: bil. Euros | Deposit Rates: 1992–2002 (60l)[d], 2003–2011 (60lhn) Lending Rates: 1992–2002 (60p)[d] 2003–2011 (60pns) | PPI (63) CPI (64) | GDP (99b.c) 1992–1998: tril. Lire 1999–2011: bil. Euros Unemployment Rate (67r)[d] |

**APPENDIX TABLE 1**
(CONTINUED)

| No. | Country | Exchange Rate [P/A][a] | Money Stock [EoP][b] | Interest Rate | Price Index [P/A] | Output/ Unemployment Rate |
|---|---|---|---|---|---|---|
| 6 | Nether-lands (Euro) | (rf) 1992–1998: Guilders per USD 1999–2011: Euros per USD | 1992–1999: Domestic Credit (32) 2000–2011: Domestic Claims (32) 1998: missing | Deposit Rates: 1992–2002 (60l)[d], 2003–2011 (60lhn) Lending Rates: 1992–2002 (60p)[d] 2003–2011 (60pns) | Prices: Final Products (63) CPI (64) | GDP (99b.c) 1992–1998: bil. Guilders 1999–2011: bil. Euros Unemployment Rate (67r)[d] |
| 7 | Norway (Non-Euro)[c] | (rf) Kroner per USD | 1992–2006: Domestic Credit (32), Money (34), Quasi Money (35) 1996–2010: Broad Money (M2, 59mb) 1992–1995: Broad Money (39m) 1992–2011: Domestic Credit (C1) from www. norges-bank.no | Deposit Rates: 1992–2009 (60l)[d] Lending Rates: 1992–2009 (60p)[d] | Prices: Final Products (63) CPI (64) | GDP (99b) Unemployment Rate (67r)[d] |
| 8 | Spain (Euro) | (rf) 1992–1998: Pesetas per USD 1999–2011: Euros per USD | 1992–1999: Domestic Credit (32) 2000–2011: Domestic Claims (32) 1992–1998: bil. Pesetas 1999–2011: bil. Euros | Deposit Rates: 1992–2002 (60l)[d], 2003–2011 (60lhn) Lending Rates: 1992–2002 (60p)[d] 2003–2011 (60pns) | Industrial Prices (63) CPI (64) | GDP (99b.c) 1992–1998: bil. Pesetas 1999–2011: bil. Euros Unemployment Rate (67r)[d] |
| 9 | Sweden (Non-Euro) | (rf) Kronor per USD | 1992–2000: Domestic Credit (32) 2001–2011: Domestic Claims (32) 1998–2011: M2 (59mb) 1996–2011: M3 (59mc) 1992–2006: M3 from www. riksbank.se | Deposit Rates: 1992–2005 (60l)[d] Lending Rates: 1992–2005 (60p)[d] | Prices: Domestic Supply (63) CPI (64) | GDP (99b) bil. Kronor Unemployment Rate (67r)[d] |

**APPENDIX TABLE 1**
(CONTINUED)

| No. | Country | Exchange Rate [P/A][a] | Money Stock [EoP][b] | Interest Rate | Price Index [P/A] | Output/ Unemployment Rate |
|---|---|---|---|---|---|---|
| 10 | Switzerland (Non-Euro) | (rf) Francs per USD | Domestic Credit (32), Money (34), Quasi Money (35) bil. Francs | Deposit Rates: 1992–2011 (60l)[d] Lending Rates: 1992–2011 (60p)[d] | PPI (63) CPI (64) | GDP (99b.c) bil. Francs Unemployment Rate (67r)[d] |
| 11 | United Kingdom (Non-Euro) | (rh) USD per Pound | Domestic Credit (32) Money plus Quasi Money (35l) M4 (59md) bil. Pounds | Deposit Rates: 1992–1998 (60l)[d] from www. bankofengland. co.uk Lending Rates: 1992–2011 (60p)[d] | Prices: Manufacturing Output (63) CPI (64) | GDP (99b.c) bil. Pounds Unemployment Rate (67r)[d] |

Note: a: P/A = Period average
b: EoP = End of period
c: Euro = Euro member country, Non-Euro = Non-Euro member country
d: Classification code in the IMF *IFS*
e: Periods of data availability. If not shown, data for the entire period of 1992–2011 are present.
f: GDP is nominal value.

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