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Robust panel unit root tests for the velocity of money in a sample of the OECD countries

Abstract

This paper examines the presence of unit roots in the velocity of money (both narrowly and broadly defined) for a large sample of the OECD countries, using the heterogeneous panel unit root tests developed by Im, Pesaran and Shin (2003) and Pesaran (2007). Under both the assumptions of cross sectional dependence and independence across the panel, the authors find evidence of unit roots in the velocities of money. These findings raise serious questions about the efficacy of the fixed money supply growth rules in the conduct of monetary policy, at least in the context of the OECD countries.

Keywords: monetary policy, OECD countries, money velocity.
JEL Classification: E52.

Introduction

Testing for unit roots in macroeconomic and financial time series has now become a constant feature and an integral part of most empirical work in dynamic econometrics. As pointed out by Campbell and Perron (1991), the presence of unit roots has important implications for both theoretical and empirical research. In particular, it indicates that the short run departures of the underlying variables from their long run equilibrium values are fairly persistent and irreversible, a finding which is at odds with many of the existing theories of economic and financial behavior, where such departures are assumed to be short-lived and self-correcting. Given the unfamiliar implications of unit root processes, there have been attempts to either justify them by new theoretical models, or reject them based on more powerful unit root tests. Examples of the first include the development of the real business cycle theory (Kydland and Prescott, 1982) to explain the presence of unit roots in real outputs, and the efficient markets hypothesis (Fama, 1991) to justify the random walk character of the stock prices. At the same time, a host of more powerful unit root tests have been devised which draw on the Bayesian (Schotman and van Dijk, 1991), nonlinear autoregression (Balke and Fomby, 1997; Perron, 1989; Zivot and Andrews, 1992; Enders and Granger, 1998; Kapetanios, Shin and Snell, 2002), and panel data approaches (Levin and Lin, 1993; Maddala and Wu, 1999; Im, Pesaran and Shin, 2003; Pesaran, 2007).

Among the above unit root tests, the panel data approach has received considerable attention in recent years (see Hsiao, 2007, for an excellent survey). The rapid spread of panel unit root tests stems from the fact that the standard augmented Dickey Fuller (1981; henceforth ADF) unit root test which relies on individual time series has limited power in differentiating between nonstationary and stationary but persistent autoregressive processes. Following the pioneering work of Levin and Lin (1993) and Quah (1994), it is now recognized that using panels can enhance the power of the ADF test, especially for small samples. This recognition has come at an opportune time, since there is now a wide array of panel data available which encompass both numerous members and long sample durations. More recently, the panel unit root tests have been extended to allow for both heterogeneity and cross section dependence of the panel members, thus offering more realistic alternative hypotheses (Maddala and Wu, 1999; Im, Pesaran and Shin, 2003; Moon and Perron, 2004; Pesaran, 2007).

Given the preceding discussion, this paper attempts to illustrate the use of the panel data unit root tests by analyzing the time series behavior of the velocity of money (both narrowly and broadly defined) in a large sample of the OECD countries over the 1986-2011 period. As such, our results should shed some additional light on the empirical issue of the stability of the velocity of money. The stability of the velocity of money is called for to render the various fixed money supply growth rules prevalent in the monetarist literature optimal in the conduct of monetary policy (Friedman, 1969; Friedman and Schwartz, 1982; Taylor, 1993; Sargent and Serico, 2011). In this connection, Gould and Nelson (1974), Nelson and Plosser (1982), Haraf (1986), Friedman and Kuttner (1992) and Serletis (1995) find evidence which they interpret as inconsistent with the stability of the velocity of money. On the other hand, Meltzer (1963), Wilbratte (1975), Lucas (1980), Siklos (1993), Choudhry (1996), Bordo, Jonung and Siklos (1997), Mehra (1997), and Anderson and Rasche (2001), present evidence in support of the proposition that the velocity is stable. None of these earlier studies, however, has relied on the panel unit roots test framework to assess the stationarity of the velocity of money. In this light, our paper can be interpreted as an attempt to advance the empirical evidence on the behavior of the velocity by relying on a more robust time series approach. More specifically, this paper tests for the nonstationarity of the velocity of money in the context of a panel of major OECD countries for the 1986-2011 period.

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Thus, our study covers a larger number of major industrial countries and for a longer span of time than many earlier studies. In addition, we explicitly test and find cross sectional dependence among the panel members, a finding that necessitates the use of the more powerful Pesaran (2007) panel unit root test.

The rest of the paper is organized as follows. Section 1 discusses the econometric methodology employed. Section 2 presents the empirical results. The final Section concludes the paper.

1. Model

Friedman (1956) provides a forceful case for the importance of the velocity of money to the conduct of monetary policy, basing his assertion on both theoretical arguments and statistical evidence. Essential to Friedman's reasoning is the stationarity of the velocity of money in the standard equation of exchange, which can be written as follows:

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

where M is the money supply (narrowly or broadly defined), V is the corresponding velocity of money, P is the general price level, and Y is the real national output. The above equation can be slightly rewritten in terms of the rates of growth of the relevant variables, as follows:

$$\Delta M/M + \Delta V/V = \Delta(PY)/(PY). \tag{2}$$

Under these conditions, it is clear that should the velocity follow a stationary process, such as mean or trend reversion, a fixed money supply growth can have a predictable effect on the growth rate of the nominal output. In contrast, any erratic behavior in the velocity can doom efforts to control changes in the nominal output through targeting the money supply. Thus, the credibility of the monetarist fixed money supply rule in the conduct of monetary policy boils down to an empirical test of whether the velocity of money can be adequately modeled by a stationary process. This test will be performed in the following pages.

2. Methodology

As stated earlier, the main objective of this paper is to test the null hypothesis of unit roots in the velocity of both narrow and broad money for a sample of the OECD countries, using the recently developed panel unit root tests. The case for panel unit root tests rests on the fact that the standard ADF unit root test for individual time series often suffers from limited power. One can, of course, increase the power of the ADF test by extending the life of the series, but this may be complicated by the possible presence of regime shifts and other structural breaks over longer time spans. Under these conditions, the addition of cross section variability to that of time variability can potentially improve the power of the standard unit root tests (e.g., Levin and Lin, 1993; see, however, Maddala, 1998, for a contrary view). More specifically, Levin and Lin (LL, henceforth) start from the standard ADF test for each of the N members of a panel over T periods, as follows:

$$\Delta y_{i,t} = \alpha_{\text{i}} + \rho y_{i,t-1} + \sum_{j=1}^{j=p_i} \beta_{i,j} \Delta y_{i,t-j} + \varepsilon_{i,t}, \tag{3}$$

where $i = 1,\ldots., N$, $t = 1,\ldots., T$, and $\varepsilon_{i,t} \approx idd\ (0, \sigma_i^2)$. In this test, the null and alternative hypotheses are, respectively, defined as:

$$H_0 : p = 0, \tag{4}$$

$$H_1 : p < 0. \tag{5}$$

Under suitably stipulated conditions, LL show that their pooled estimate of ρ follows a standard normal distribution. One limitation of the LL test, however, is its reliance on a uniform speed of adjustment across all panel members, an assumption too unrealistic to be of much use in real applications (e.g., Maddala and Wu, 1999). This limitation was subsequently addressed by Im, Pesaran and Shin (2003), where they assume that panel members have different speeds of adjustment. In particular, the Im, Pesaran and Shin (IPS, henceforth) test is based on the following ADF regressions for all panel members:

$$\Delta y_{i,t} = \alpha_i + \rho_i y_{i,t-1} + \sum_{j=1}^{j=p_i} \beta_{i,j} \Delta y_{i,t-j} + \varepsilon_{i,t}, \tag{6}$$

where the null and alternative hypotheses are now defined as:

$$H_0 : p_i = 0, \text{ for all } i = 1,\ldots., N, \tag{7}$$

$$H_1 : p < 0, \text{ for some } i = 1,\ldots., N. \tag{8}$$

Once the separate ADF regressions for all panel members are estimated, IPS propose their $\bar{t}$ test statistic as the average of the corresponding ADF t-statisitcs (t_i), as shown below:

$$\bar{t} = \frac{1}{N} \sum_{i=1}^{N} t_i. \tag{9}$$

Furthermore, under the assumption of cross sectional independence, and using the Lindberg-Levy central limit theorem, IPS show that their $\bar{t}$ statistic has an asymptotically normal distribution. To standardize the $\bar{t}$ distribution, IPS use Monte Carlo simulations to compute the mean (μ) and variance (var) of the ADF t-statistic for different values of N, T and ADF lag (p_i). To ensure identical distribution for the ADF t-statistic across all panel members, the IPS test is often used in the context of balanced panels (same T) with the same ADF lag length. Under these conditions, the standardized $\bar{t}$ statistic, de-

noted by $\bar{z}$, can be written as:

$$\bar{z} = \frac{\sqrt{N}(-\mu)}{\sqrt{var}}. \quad (10)$$

As stated earlier, a major shortcoming of the panel unit root tests discussed above is their assumption of cross sectional independence across the panel members. As pointed out by O'Connell (1998), the unwarranted adoption of this assumption can seriously distort the size of the standard panel root tests. Consequently, a number of researchers have tried to address this issue in the context of various factor and error component models (Choi, 2002; Phillips and Sul, 2003; and Pesaran, 2007). In particular, Pesaran (2007) offers a modified version of the IPS test, in which the standard ADF test is further augmented by the lagged values of the level and first differences of the cross section average of the individual series:

$$\Delta y_{i,t} = \alpha_i + \rho_i y_{i,t-1} + c_{ii,t-1+}\bar{y}_{i,t-1} + \sum_{j=1}^{j=\rho_i} \beta_{i,j}\Delta y_{i,t-j} + \\ + \sum_{j=0}^{j=\rho_i} d_{i,j}\Delta \bar{y}_{i,t-j} + \nu_{i,t}, \quad (11)$$

where $\overline{y_t} = \frac{1}{N}\sum_{i=1}^{N} y_{i,t}$. Following a procedure similar to IPS, the Pesaran test is now based on the average of the CADF (cross sectionally augmented ADF) t-statistics for the significance of ρ_i in equation 9:

$$\overline{tt} = \frac{1}{N}\sum_{i=1}^{N} t_i. \quad (12)$$

Furthermore, since the panel members are cross sectionally dependent, the $\overline{tt}$ statistic does not have an asymptotic normal distribution. Thus, using simulations, Pesaran offers the critical values of the standardized version ($\overline{zz}$, hereafter) of this statistic for various sample and panel sizes.

As the foregoing makes it clear, before the application of the above panel root tests, it is necessary to ascertain whether the underlying panels are characterized by the presence of cross sectional dependence. To this end, we can use the diagnostic techniques developed by Breusch and Pagan (1980) and Pesaran (2004). Specifically, the Breusch-Pagan Lagrange Multiplier (LM) test is based on the following test statistic:

$$LM = T\sum_{i=1}^{N-1}\sum_{j=i+1}^{N} \rho_{ij}^2. \quad (13)$$

Where p_{ij} is the Pearson correlation coefficient between the estimated residuals from the ADF regressions of the panel members i and j. Under the null of no cross sectional dependence, the LM statistic has a chi-squared distribution with N (N – 1)/2 degrees of freedom. Similarly, the Pesaran cross sectional dependence (CD) test is based on the following test statistic:

$$CD = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N} \rho_{ij}^2\right), \quad (14)$$

where p_{ij} is defined as before. Under the null of no cross sectional dependence, the Pesaran CD statistic has asymptotically a standard normal distribution.

3. Empirical results

In this section, we present the empirical results of testing for the presence of unit roots in the velocity of money (both narrowly and broadly defined) for a large sample of the OECD countries, using the methodology discussed in the preceding section. In addition to Canada, Denmark, Japan, Turkey, UK and US, which are not members of the European Monetary System (EMS), we also use the aggregate data for the entire EMS membership. The data, which are taken from the OECD files of the RATS software package, are monthly, calculated as the logs of the velocity, and cover the 1986, p. 9-2011, 1 period. Furthermore, to facilitate exposition, we initially report the empirical results for the velocity of narrow money (currency in circulation and demand deposits), and subsequently proceed to the properties of the velocity of broad money (defined to include savings and time deposits).

3.1. Velocity of the narrow money. As a first step in the analysis of the time series properties of the velocity of the narrow money for our sample countries, this section conducts the standard Dickey-Fuller unit root tests of these velocities against the alternative hypotheses that they are stationary around linear trends. As is well known, the implementation of the Dickey-Fuller test requires the whitening of the error terms associated with the auxiliary equations of these tests by adding an appropriate number of lags of the first differences of the underlying variables to these equations. To establish the appropriate lag length for the sample countries, the Akaike information criterion (Akaike, 1973) is used for a VAR in all the velocities. Starting from a maximum lag of twelve months, the Akaike procedure selected a lag of eight months. The augmented Dickey-Fuller (ADF) unit root test results for the velocity of narrow money are given in Table 1.

Table 1. ADF unit root test results for the narrow velocity

Country	*t* test	Country	*t* test
Canada	-2.33	Turkey	-1.72
Denmark	-2.55	UK	-2.24
EMS	0.01	US	-1.14
Japan	-0.99		

Source: * Indicates significant at the 5 percent level.

As seen from the Table, the null of a unit root cannot be rejected for any of the countries in the sample, indicating the absence of trend-reversion for the velocity of the narrow money in an overwhelming majority of the OECD countries. This finding is a clear rejection of the empirical case for the fixed money supply growth rules in the conduct of monetary policy for most OECD countries, at least in the context of the narrow definition of money.

Having established the random walk behavior of the narrow velocity within the ADF framework, this section now proceeds to examine the time series properties of these velocities within a panel unit roots model. As stated in the preceding section, the use of the OECD panel should provide additional power to our ADF unit root tests. As a first step, we therefore, use the IPS test, ignoring momentarily the issue of the cross sectional dependence of the panel members. To this end, as stated earlier, we separately estimate the standard ADF regression for each panel member, and then calculate the corresponding IPS $\bar{z}$ statistic as defined by 5 above. As seen before, the $\bar{z}$ statistic has an asymptotic normal distribution. Based on the value of $\bar{z}$ for our panel, -0.34, which is insignificant at the 5 percent level, it is clear that the IPS test cannot reject the null hypothesis of unit roots for our panel. That is, our panel root test results are consistent with our earlier ADF test results, indicating no trend reversion in the velocity of narrow money in the context of our sample countries. As discussed earlier, however, the IPS test results can be spurious in the presence of cross sectional dependence across panel members. Thus, it is important to test for cross sectional dependence of velocities among our sample countries.

The cross sectional dependence of panels can be tested based on the LM and CD diagnostic tests alluded to earlier in the paper. The implementation of these tests requires that we first estimate the pairwise correlations for all the residuals from the ADF regressions run separately for individual panel members. Based on these estimated residuals, we can then calculate the corresponding correlations and their associated diagnostic test statistics. The Breusch-Pagan LM statistic, which has a chi-squared distribution with 42 degrees of freedom for our sample, has a value of 2,741.52 and is, thus, highly significant at the 5 percent level. Likewise, the Pesaran CD test statistic, which has a standard normal distribution, has a value of 23.45, again highly significant at the 5 percent level. Thus, both our diagnostic tests strongly reject the null hypothesis of no cross sectional dependence for our sample countries. Clearly, these findings render the application of the IPS test in its original form untenable. Under these conditions, the correct methodology is provided by the Pesaran modified IPS test, as discussed earlier.

To apply the more robust Pesaran test, we first separately estimate the cross sectionally augmented ADF regression 9 (CADF) for all sample countries. The results are reported in Table 2. Next, we find the cross sectionally modified IPS statistic ($\overline{tt}$) as the average of the standard *t*-statistics from the estimated CADFs. The standardized value of this statistic ($\overline{zz}$) can then be compared to the critical values tabulated by Pesaran to assess its significance. The estimated $\overline{zz}$ statistic has a value of 2.01, which is larger than the 5 percent critical value of -2.22 provided by Pesaran. This means that at the 5 percent level of significance, we cannot reject the null hypothesis of unit roots in the narrow velocities for our sample countries. Again, these results are consistent with those found earlier for our standard IPS test, where the issue of the presence of cross sectional dependence across our panel members was ignored. Based on these more robust test results, we can raise serious questions about the optimality of the fixed money supply rules widely proposed in the monetarist literature.

Table 2. CADF Unit root test results for the narrow velocity

Country	*t* test	Country	*t* test
Canada	-1.28	Turkey	-2.56
Denmark	-2.64	UK	-1.71
EMS	-2.67	US	-1.84
Japan	0.60		

3.2. Velocity of the broad money. As it was the case for the narrow velocity, as a first step in the analysis of the time series properties of the broad velocity for our sample countries, we start by the augmented Dickey-Fuller unit root tests of these velocities against the alternative hypotheses that they are stationary around linear trends. To establish the appropriate lag length for the sample countries, the Akaike information criterion (Akaike, 1973) is used for a VAR in all the velocities. Starting from a maximum lag of twelve months, the Akaike procedure selected a lag of three months. The augmented Dickey-Fuller (ADF) unit root test results for the velocity of the broad money are given in Table 3.

Table 3. ADF unit root test results for the broad velocity

Country	*t* test	Country	*t* test
Canada	-1.74	Turkey	2.24
Denmark	-2.82	UK	-3.24
EMS	0.64	US	-1.24
Japan	-3.20		

Source: * Indicates significant at the 5 percent level.

As seen from the Table, the null of a unit root cannot be rejected for any of the countries in the sample, indicating the absence of trend-reversion for the veloc-

ity of the broad money in an overwhelming majority of the OECD countries. This finding is a clear rejection of the empirical case for the fixed money supply growth rules in the conduct of monetary policy for most OECD countries, even in the context of the broad definition of money.

Having established the random walk behavior of the broad velocity within the ADF framework, this section now proceeds to examine the time series properties of these velocities within a panel unit roots model. Again, as a first step, we use the IPS test, ignoring momentarily the issue of the cross sectional dependence of the panel members. To this end, as stated earlier, we separately estimate the standard ADF regression for each panel member, and then calculate the corresponding IPS $\bar{z}$ statistic as defined by 5 above. As seen before, the $\bar{z}$ statistic has an asymptotic normal distribution. Based on the value of $\bar{z}$ for our panel, 0.46, which is insignificant at the 5 percent level, it is clear that the IPS test cannot reject the null hypothesis of unit roots for our panel. That is, our panel root test results are again consistent with our earlier ADF test results, indicating no trend reversion in the velocity of the broad money in the context of our sample countries. As discussed earlier, however, the IPS test results can be spurious in the presence of cross sectional dependence across panel members. Thus, it is important to also test for cross sectional dependence of our velocities among our sample countries, using once again the Breusch-Pagan and Pesaran diagnostic test statistics.

The Breusch-Pagan LM statistic, which has a chi-squared distribution with 42 degrees of freedom for our sample, has a value of 2,647.02 and is, thus, highly significant at the 5 percent level. Likewise, the Pesaran CD test statistic, which has a standard normal distribution, has a value of 43.08, again highly significant at the 5 percent level. Thus, both our diagnostic tests strongly reject the null hypothesis of no cross sectional dependence for our sample countries. Clearly, these findings once more require the application of the more robust Pesaran test.

To apply the Pesaran test, we again separately estimate the cross sectionally augmented ADF regression 9 (CADF) for all sample countries. The results are reported in Table 4.

Table 4. CADF Unit root test results for the broad velocity

Country	*t* test	Country	*t* test
Canada	-2.69	Turkey	-1.09
Denmark	-2.47	UK	-7.62
EMS	-2.81	US	-0.70
Japan	-2.62		

We find the cross sectionally modified IPS statistic ($\overline{tt}$) as the average of the standard *t*-statistics from the estimated CADFs. The standardized value of this statistic ($\overline{zz}$) can then be compared to the critical values tabulated by Pesaran to assess its significance. The estimated $\overline{zz}$ statistic has a value of -1.60, which is larger than the 5 percent critical value of -3.03 provided by Pesaran. This means that at the 5 percent level of significance, we cannot reject the null hypothesis of unit roots in the narrow velocities for our sample countries. Again, these results are consistent with those found earlier for our standard IPS test. Based on these more robust test results, we can question the optimality of the fixed money supply rules even when they are based on the broad definition of money.

Conclusion

This paper has examined the presence of unit roots in the velocities of narrow and broad money for a large sample of the OECD countries for the 1986-2011 period, using the heterogeneous panel unit root tests developed by Im, Pesaran and Shin (2003) and Pesaran (2007). Under both the assumptions of cross sectional independence and dependence across the panel, we have found substantial evidence of unit roots, thus failing to accept trend reversion in these velocities for all the countries in the sample. The paper has also shown that these findings are consistent with those based on the conventional Dickey-Fuller unit root test results. If valid, these findings have important implications for the optimal conduct of monetary policy, an issue still debated in the monetarist literature. To the extent that money velocities have no clear tendency towards trend reversion, any monetary shocks to the OECD countries can only be addressed through deliberate and vigorous monetary policies, rather than a reliance on market forces. In other words, in the absence of discretionary policies, deviations from the equilibrium in the money markets can be frequent and fairly persistent.

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