E C O N O M I C S   B U L L E T I N

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BARHOUMI Karim
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Citation: Karim, BARHOUMI, (2005) "Exchange Rate Pass−Through Into Import Prices In Developing Countries: An Empirical Investigation." *Economics Bulletin,* Vol. 3, No. 26 pp. 1−14
Submitted: November 16, 2004. **Accepted:** May 17, 2005.
URL: http://www.economicsbulletin.com/2005/volume3/EB−04C50035A.pdf

Exchange Rate Pass-Through Into Import Prices In Developing Countries: An Empirical Investigation

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November 15, 2004

Abstract

We define and estimate an exchange rate pass-through equation for 24 developing countries. We find that long run exchange rate pass-through into import price is determined by a combination of nominal effective exchange rate, the price of the competing domestic product, the exporter's cost and domestic demand conditions. Adopting a multi-country framework and using non-stationary panel estimation techniques and tests for panel cointegration, we show that exchange rate pass-through in developing countries is heterogeneous.

1 Introduction

Exchange rate pass-through is one of the main issues in international economics, in particular exchange rate pass-through into import prices, which is broadly defined as the percentage change in import prices caused by one percent change in exchange rate. Since the 1980s, there has been an important empirical literature on exchange rate pass-through into import prices. Most of the empirical studies have focused on the industrialized countries, particularly the US and Japan (see a survey by Menon (1995) or Goldberg and Knetter (1997)). However, a few studies on exchange rate pass-through have been done for developing countries (see Rana and Dowling (1985) and Alba and Papell (1998)), except for example Sahminan (2003), who compares the coefficients of the pass-through between different countries in Southeast Asia.

This paper is precisely a contribution to the analysis of the exchange rate pass-through into import prices in developing countries. The prevalent idea is that the economic peculiarities of these countries are in practice similar. Indeed, most of the developing countries are strongly dependent on international trade. These countries are not able to control their products sold in the international market, as well as their market shares; in most cases, these countries are "price taker" . Moreover, developing countries are characterized by marginal industrial activities. This weakness makes them dependent on importations from industrial countries. Besides these similarities, we are interested in the nature of the long run exchange rate pass-through into import prices; more precisely, we try to know if the long run exchange rate pass-through phenomenon in developing countries is homogeneous or heterogeneous. We thus define and estimate an exchange rate pass-through equation across a panel of 24 developing countries using the model of Bache (2002) and Sahminan (2003). It stipulates that the degree of exchange rate pass-through into import prices is determined by a combination of nominal effective exchange rate, the price of competing domestic products, the exporter's cost and domestic

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demand conditions. Adopting a multi-country framework and using non-stationary panel estimation techniques and tests for panel cointegration, we prove the existence of an equilibrium relation between import prices and the other variables and we show that exchange rate pass-through in developing countries is heterogeneous.

The remainder of the paper is organized as follows. First, we introduce our theoretical model from which we define our price equation. Secondly, we perform the stationarity and cointegration tests. Then, by using the appropriate estimation techniques of our long run relation, we show that the long run exchange rate pass-through in developing countries is heterogeneous. Finally, we provide some concluding remarks.

2 The theoretical model

In this paper, the model that we use to estimate the degree of the exchange rate pass-through into import prices is similar to the model used in a long part of the literature in this area (Hooper and Mann (1989), Goldberg and Knetter (1997) and Campa and Goldberg (2002)). We consider a representative foreign firm having some degree of control over the price of its goods in an importing country. Assume that this representative firm establishes the price of its exports to country i (i is a developing country) in its own currency (PX_{it}) at a markup (λ_{it}) over its marginal cost of production (C^*_{it}), that is:

$$PX_{it} = \lambda_{it} C^*_t. \tag{1}$$

The import price in the domestic currency PM_{it} is obtained by multiplying export price PX_{it} by the exchange rate of the importing country i, E_{it}, that is,

$$PM_{it} = E_{it} PX_{it} = E_{it} \lambda_{it} C^*_t. \tag{2}$$

The markup is assumed to respond to both demand pressure for exporting country (Y^*_{it}) and competitive pressure in importing country. Competitive pressure in importing country is measured by the gap between the competitors prices in the importing country market (P_{it}) and production cost of exporting firm. Therefore, the markup λ_{it} is given by:

$$\lambda_{it} = \left[\frac{P_{it}}{E_{it} C^*_{it}} \right]^{\alpha} Y^{*\beta}_{it} \qquad 0 < \alpha < 1 \text{ and } \beta > 0. \tag{3}$$

Substituting equation (3) into equation (1), we obtain

$$PM_{it} = (E_{it} C^*_{it})^{1-\alpha} (P_{it})^{\alpha} Y^{*\beta}_{it}. \tag{4}$$

The logarithmic form of the equation (4) is thus:

$$pm_{it} = (1-\alpha) e_{it} + (1-\alpha) c^*_{it} + \alpha p_{it} + \beta y^*_{it}. \tag{5}$$

Where lowercase letters denote the logarithmic values of the variables.

In equation (5), the exchange rate pass-through, defined as the partial elasticity of import price with respect to exchange rate, is $(1-\alpha)$. One weakness of this model is that the pass-through of exchange rate and foreign cost into import price are the same. However, in practice, this restriction does not necessarily hold (see Bache (2002)). Therefore, in estimation, we relax these restrictions and consider the following equation (the long-run equation):

$$pm_{it} = \alpha_i + \beta_1 e_{it} + \beta_2 c^*_{it} + \beta_3 p_{it} + \beta_4 y^*_{it} + \varepsilon_{it}. \tag{6}$$

In this equation, the marginal cost of production of foreign firm is difficult to measure, therefore we adopt the Wholesale price movements of major trade partners of country i (see Eiji Fujii (2004) represented by :

$$C^*_{it} = Q_{it} \times \frac{\widetilde{P}_{it}}{E_{it}}. \tag{7}$$

where we have E_{it}: nominal effective exchange rate of country i, $\widetilde{P}_{it}$: the wholesale price index of country i and Q_{it}: real effective exchange rate of country i. Taking the logarithm of each variable form, we consider:

$$c_{it}^{*} = q_{it} - e_{it} + \widetilde{p}_{it}. \tag{8}$$

About the other variables in equation (7), the proxy for domestic competitor's price P_{it} is the Producer Price Index of country i (PPI). As the proxy for the demand pressure Y_{it}^{*}, we use GDP of country i and, for import price PM_{it}, we take the import unit value in domestic currency.

3 Data and Panel tests for unit root and cointegration

3.1 Data Sources

The main problem in empirical studies on developing countries is data availability. Indeed, because the difficulty to find some variables such as the nominal effective exchange rate, we consider a panel of 24 developing countries. The data are annual and span the period 1980- 2003 (24 years). They are obtained from International Financial Statistics.

3.2 Panel unit root tests

The first step when analyzing the long run relationship is to test for stationarity of the individual variables. We apply two tests proposed respectively by Im, Pesaran and Shin (1997) (henceforth IPS) and Hadri and Larson (2001) (henceforth HL). The latter test has two main advantages when compared with the classical IPS methodology. Firstly, it avoids the lack of power of the unit root-based tests by assuming stationarity under the null hypothesis. Secondly, it is particularly adapted for panel data series with short time dimension, which is the case in this paper.

IPS tests results are shown in table 1. We compare statistics to the critical values given in table 4 of Im, Pesaran and Shin (1997) at 5% level for N=24 and T=24. We thus conclude that all variables are stationary in first difference. Hadri and Larson tests results are shown in table 2. We confirm the results found for the IPS tests (all variables are stationary in first difference).

3.3 Tests for panel cointegration

There are several panel cointegration tests, in particular Pedroni's tests (1995,1999) and Kao (1999). We use only the Pedroni's tests because they are more robust in presence of heterogeneity in panel data with regard to the Kao tests. As shown in table 3, all tests statistics reject the null of no cointegration.[1]

4 Long run exchange rate pass-through estimations

4.1 PMG and MG Estimations

To obtain estimation of long run coefficients of the cointegration relationship (6), we use two different estimators: the « Pooled Mean Group estimator »(PMG) and the « Mean Group estimator » (MG). The first estimator is proposed by Pesaran, Shin and Smith (2000) for heterogeneous dynamic panel models. The PMG method restricts the long-run coefficients to be equal over the cross-sections but allows for the short-run coefficients and error variance to differ across groups on the cross-sections.

[1] Except the v-stat, all tests statistics have a critical value of -1.64 (if the test statistic is less than -1.64, we reject the null of no cointegration). The v-stat has a critical value of 1.64 (if the test statistic is greater than 1.64, we reject the null of no cointegration).

The second estimator, proposed by Pesaran & Smith (1995), is an average of N individual estimations allowing long-run heterogeneity. We test for long run homogeneity using a joint Hausman test based on the null hypothesis of equivalence between the PMG and MG estimation. If we reject the null, we reject the homogeneity of our cross-section's long-run coefficients.

We estimate the following model:

$$\Delta p_{it}^{im} = \phi_i p_{it-1}^{im} + \beta_i^{'} x_{it} + \sum_{j=1}^{p-1} \lambda_{ij}^{*} \Delta p_{it-j}^{im} + \sum_{j=0}^{q-1} \delta_{ij}^{*} \Delta x_{it-j} + \mu_i + \varepsilon_{it} \tag{9}$$

where x_{it} is the vector of explanatory variables : $e_{it}, c_{it}^{*}, p_{it}$ and y^{*}.

The PMG and MG estimations [2] are shown in table 4. First, PMG and MG estimation provide a significant long-run pass-through coefficient (respectively 0.637 and 0.7265). Secondly, by the joint Hausman test, we reject long-run homogeneity with a probability value of 0.03. So, following these results, we conclude that the long run exchange rate pass-through into import prices in developing countries is an heterogeneous phenomenon. Therefore, we are going to use estimation techniques taking into account the heterogeneity of long-run coefficients.

4.2 Mean Group Panel Estimations

The classical FMOLS and DOLS estimators based on the within dimension do not allow for long –run heterogeneity coefficients. We use FMOLS and DOLS between-dimension estimators (Group Mean Estimator) proposed by Pedroni (2001). An important advantage of the between-dimension estimators is that the form in which the data are pooled allows for greater flexibility in the presence of heterogeneous cointegrating vectors. Another advantage is that the estimates have a more useful interpretation when the true cointegrating vectors are heterogeneous. Specifically, the estimates for the between dimension estimator can be interpreted as the mean value for the cointegrating vectors, this is not true for the within-dimension estimations.

By analyzing FMOLS and DOLS estimations results, we notice a great heterogeneity of long-run coefficients (cross-sectional estimations), in particular of the long-run exchange rate pass-through coefficients. By FMOLS, the greater long run pass-through coefficient is for Costa Rica (203%) and the smaller one is Iran (27%) (see table 7). Similarly, DOLS estimation gives 209% for Costa Rica and 37.7% for Iran (see table 8). Theoretical arguments for cross-country heterogeneity in long run exchange rate pas-through into import prices can depend firstly on the stability of local monetary policy (Devereux and Engel (2001) and Bacchetta and Van Wincoop (2001)). If exporters set their prices in the currency of the country that has the most stable monetary policies, import prices in local currency terms would be more stable in countries with more stable monetary policy. All else equal, long-run exchange rate pass-through would be higher for countries with more volatile monetary policy. Secondly, country size may be another important factor for heterogeneity of long-run exchange rate pass-through. As exposed by Dornbusch (1987), long-run exchange rate pass-through into import prices may be higher if there is a lot of exporters relatives to the presence of local competitors. Exchange rate pass-through might be inversely related to country real GDP. On average, we obtain by FMOLS, an estimation of long-run exchange rate pass-through of 77.25% and by DOLS of 82.7 (see tables 5 and 6). Besides the heterogeneity of long-run exchange rate pass-through, these results confirm the hypothesis that developing countries are characterized (on average) by a high long-run exchange rate pass-through into import prices.

[2] All PMG and MG estimations was performed using the GAUSS code written by Yongcheol Shin. The program is available on line at http://www.eco.cam.ac.uk/faculty/pesaran/jasa.exe

5 Concluding remarks

In this paper we estimate long-run exchange rate pass-through into import prices equations for a panel of 24 developing countries using a non stationary panel approach. The advantage of this approach is to use the additional information available in the cross-section in order to increase the power tests to identify no-spurious cointegration between the variables in respect to single country tests.

We considered that exchange rate pass-through is determined by a combination of nominal effective exchange rate, the price of competing domestic product, the exporter's cost and domestic demand conditions We show that there is some evidence of cointegration between all variables. By estimating our long-run relationship, we find that the long-run exchange rate pass-through into import prices in developing countries is heterogeneous. We can argue that this heterogeneity can depend on economic peculiarities of developing countries such as local monetary policy and country size.

There are a variety of directions for future research, more precisely we can focus on other heterogeneous sources of long run exchange rate pass-through in developing countries such as exchange rate regime and trade policy.

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Table 1: **IPS panel unit root tests results**

variables	level		first difference	
	intercept	intercept+ trend	intercept	intercept + trend
pim	-1.2523	-0.9320	-7.4207	-7.8963
en	-1.4896	-2.1891	-3.4995	-3.1059
ppi	-1.5230	-0.8950	-5.8498	-5.9156
y*	-1.2421	-1.5449	-5.0163	-5.9311
c*	-1.4391	-0.9553	-3.7921	-3.1629

Note: The critical value at 5% is -1.73 for model with an intercept and -2.45 for model with intercept and linear time trend.

Table 2: **Hadri and Larson panel unit root tests results**

variables	level	first difference
en	4.9286	1.3298
pim	3.6727	0.9783
ppi	6.1436	-2.2341
y*	2.4789	-3.7658
c*	2.3267	0.7658

Note: The null of stationarity is rejected if the computed HL statistic is greater than 1.645 at 5% level.

Table 3: **Pedroni's cointegration tests results**

Statistics	*values*
Panel v-stat	2.4385**
Panel rho-stat	-2.8816**
Panel pp-stat	-2.5329**
Panel adf-stat	-3.2385**
group rho-stat	-3.4090**
group pp-stat	-3.1661**
group adf-stat	-2.3043**

Table 4: **PMG and MG estimations**

Estimators	**PMG**		**MG**	
variables	**coefficients**	**t-values**	**coefficients**	**t-values**
en	**0.637**	**7.968**	**0.7265**	**2.434**
ppi	**0.449**	**11.859**	**0.2371**	**2.722**
y*	**0.454**	**10.841**	**0.3934**	**6.021**
c*	**0.327**	**2.761**	**0.2963**	**1.299**

Table 5: **FMOLS Mean Group Panel estimation**

Estimator	FMOLS	
variables	coefficients	t-values
en	0.7725	2.3541
ppi	0.24375	5.9475
y*	0.48666	2.5467
c*	0.28667	4.1787

Table 6: **DOLS Mean Group Panel estimation**

Estimator	DOLS	
variables	coefficients	t-values
en	0.8278	6.3221
ppi	0.3031	4.1787
y*	0.9203	2.2562
c*	0.2912	2.2347

Tableau 7: **FMOLS estimations by country**

countries	en	ppi	y*	c*
1-Algeria	1.07 (20.15)	-0.27 (-2.37)	0.33 (2.27)	-0.40 (-2.77)
2-Burkina Fasso	0.56 (3.25)	-0.35 (-0.42)	-0.68(-1.34)	-1.13(-2.26)
3-Botswana	0.37 (4.83)	0.57 (5.54)	-0.42(-1.86)	-1.26(-3.31)
4-Cote Ivoire	0.73 (15.63)	-0.28 (-1.15)	0.02(0.05)	0.03(4.18)
5-Gabon	0.43 (2.45)	0.86 (9.03)	-0.82(-4.11)	0.22(2.71)
6-Moroco	0.93 (6.20)	0.73 (1.11)	-0.17(-0.31)	1.65(1.68)
7-Nigeria	0.64 (5.17)	0.77 (2.67)	0.78 (1.10)	-1.20 (-3.06)
8-Senegal	1.11 (2.71)	-0.10 (-1.69)	1.14(3.67)	1.71 (5.44)
9-Tunisia	0.33 (3.02)	0.23 (1.10)	0.02 (10.02)	-0.31 (-0.74)
10-Zambia	0.88 (10.93)	-0.15 (-11.79)	1.69 (3.24)	1.55 (4.85)
11-India	0.55 (3.03)	1.34 (5.89)	3.60 (0.90)	-1.19 (-4.98)
12-Indonesia	0.29 (2.10)	0.62 (1.39)	-0.84 (-2.57)	-1.08 (-1.67)
13-Iran	0.27 (3.55)	0.51 (5.68)	-1.15 (-2.08)	0.98 (3.39)
14-Pakistan	0.47 (4.29)	0.48 (0.98)	0.07 (0.45)	-0.13 (-3.32)
15-Phillipines	0.68 (11.41)	0.80 (2.01)	0.18 (0.21)	0.31 (0.93)
16-Singapour	0.65 (3.69)	0.95 (2.42)	2.32 (2.05)	2.22 (0.77)
17-Bolivie	1.17 (3.64)	1.06 (4.82)	-0.08 (-0.19)	2.29 (2.41)
18-Chilie	0.42 (6.07)	-0.34 (-5.57)	0.43 (2.45)	0.10(0.76)
19-Colombia	0.74 (4.85)	4.19 (10.14)	1.52 (2.46)	2.73 (2.83)
20-Costa Rica	2.03 (2.91)	-0.29(-0.19)	0.68 (0.18)	0.87 (1.24)
21-Equateur	1.21 (1.16)	-1.59(-1.32)	7.87 (3.22)	1.38 (3.02)
22-Paragay	0.95 (2.69)	-2.10 (-4.98)	-0.18 (-1.06)	2.72 (6.91)
23-Urugay	1.02 (3.98)	0.38 (2.76)	-1.84 (-6.36)	0.05(0.32)
24-Venezuela	1.03 (2.82)	-2.17 (-5.10)	-0.17 (-0.99)	1.14 (3.27)

Table 8: **DOLS estimations by country**

countries	en	ppi	y*	c*
1-Algeria	1.34 (2.87)	0.16 (0.29)	2.52 (8.29)	0.11 (1.20)
2-Burkina Fasso	0.46 (2.66)	0.39 (0.53)	0.32 (1.76)	4.50 (9.01)
3-Botswana	0.50 (2.22)	0.72 (2.11)	0.42 (2.14)	-0.44 (1.12)
4-Cote Ivoire	1.03 (3.99)	1.44 (2.89)	0.05 (0.16)	-2.71 (-2.72)
5-Gabon	0.39 (2.76)	0.85 (2.43)	0.12 (0.89)	0.565 (0.09)
6-Moroco	1.12 (3.67)	0.95 (3.19)	0.13 (0.31)	-0.15 (-4.71)
7-Nigéria	0.45 (1.68)	0.61 (0.39)	0.23 (0.42)	2.42 (0.20)
8-Senegal	1.12 (2.54)	0.76 (1.87)	-0.83 (-3.24)	0.23 (1.79)
9-Tunisia	0.39 (3.55)	0.63 (0.26)	0.12 (0.58)	0.33 (1.11)
10-Zambia	0.42 (2.48)	-0.72 (-0.86)	1.99 (1.39)	-1.40 (-6.71)
11-India	0.97 (2.42)	-0.51 (-2.08)	1.32 (2.01)	-5.64(-0.43)
12-Indonesia	0.41 (10.38)	0.58 (0.33)	-0.14 (-0.52)	-0.50 (-3.12)
13-Iran	0.37 (2.14)	-6.14 (-5.66)	5.86 (5.42)	3.59 (1.96)
14-Pakistan	0.43 (2.37)	0.94 (3.33)	-0.14 (-2.52)	-0.12 (-0.84)
15-Phillipines	0.75 (2.11)	2.88 (1.24)	3.75 (1.61)	0.97 (2.13)
16-Singapour	0.43 (2.08)	0.68 (2.31)	0.34 (1.82)	-1.16 (-1.94)
17-Bolivie	1.63 (11.26)	0.99 (0.13)	-0.14 (-0.12)	1.21 (1.06)
18-Chilie	0.42 (2.99)	-0.24 (-0.96)	1.36 (1.16)	0.14 (0.18)
19-Colombia	0.67 (4.70)	1.43 (0.97)	-0.01 (-0.70)	0.26 (1.03)
20-Costa Rica	2.09 (6.42)	-0.60 (-0.30)	1.73 (0.33)	0.42 (0.59)
21-Equateur	1.03 (2.30)	1.25 (1.90)	0.31 (1.09)	0.80 (1.87)
22-Paragay	1.10 (3.06)	0.08 (11.06)	0.84 (16.05)	1.67 (0.85)
23-Urugay	0.95 (4.25)	0.07 (2.06)	0.36 (1.41)	0.17 (0.19)
24-Venezuela	1.29 (4.09)	-0.01 (-0.24)	1.54 (0.07)	1.09 (0.93)

Appendix

A Unit Root Tests

A.1 Im, Pesaran and Shin (1997) t-bar test

Im, Pesaran and Shin (1997) proposed a statistics calculating the average of DF and ADF statistics when residuals are serial correlated across different units.

The t-statistic for panel unit root is based on the panel version of the standard ADF regression:

$$y_{it} = \rho_i y_{it-1} + \sum_{j=1}^{p_i} \varphi_{ij} \Delta y_{it-j} + z_{it}^{'} \gamma_i + \varepsilon_{it}$$

$$u_{it} = \sum_{j=1}^{p_i} \varphi_{ij} u_{it-j} + \varepsilon_{it}. \tag{10}$$

The procedure amounts to test is $H_0 : \rho_i = 1$ for all i against $H_a : \rho_i < 1$ for at least one i. The t-bar statistic is defined as the average of ADF individuals statistic:

$$\bar{t}_{NT} = \frac{1}{N} \sum_{i=1}^{N} t_{\rho_i}. \tag{11}$$

A.2 Hadri and Larson (2001) test

Hadri and Larson (2001) propose a Lagrange multiplier test (LM) based on the residuals; its a KPSS test applied to panel data based on the following regression:

$$y_{it} = z_{it}^{'} \gamma + r_{it} + \varepsilon_{it}. \tag{12}$$

where $z_{it}^{'}$ is the deterministic component and r_{it} a random walk:

$$r_{it} = r_{it-1} + u_{it}. \tag{13}$$

where $u_{it} \sim iid(0, \sigma_u^2)$ and ε_{it} is a stationary process.

We can re-write equation(12) as follows :

$$y_{it} = z_{it}^{'} \gamma + e_{it}. \tag{14}$$

where

$$e_{it} = \sum_{j=1}^{t} u_{ij} + \varepsilon_{it}. \tag{15}$$

We note that $\widehat{e_{it}}$ and $\widehat{\sigma_e^2}$ are respectively the residuals and standard error estimations from equation (14)and S_{it} is the residual partial sum:

$$S_{it} = \sum_{j=1}^{t} \widehat{e_{ij}}. \tag{16}$$

The LM statistics is :

$$LM = \frac{\frac{1}{N} \sum_{i=1}^{N} \frac{1}{T^2} \sum_{t=1}^{T} S_{it}^2}{\widehat{\sigma_e^2}}. \tag{17}$$

B Pedroni's cointegration tests (1999)

Pedroni (1995, 1999) has developed seven tests based on the residuals from the cointegrating panel regression under the null hypothesis of non-stationarity. They are calculated using the estimated residuals from the following panel regression:

$$y_{it} = \alpha_i \ + \delta_{it} + \gamma_t + X_{it}^{'}\beta_i + e_{it} \ , \ i = 1, ..., N \ , \ t = 1, ..., T. \tag{18}$$

where $\beta_i = (\beta_{1i}, \beta_{2i}, ..., \beta_{ni})$ and $X_{it} = (x_{1i,t}, x_{2i,t}, ..., x_{ni,t})$

$$\widehat{e}_{it} = \rho_i \widehat{e}_{it-1} + \xi_{it} \tag{19}$$

The first four Pedroni tests are based on the within panel estimator, that are known as the Panel Statistics: are a variance ration test (v-statistic), a panel version of the Phillips and Perron (1988) ρ-statistic and t-statistic (non-parametric), and the ADF t-statistic (parametric). The null hypothesis is ρ_i =1 against $\rho_i = \rho < 1$. Additional three statistics are based on pooling along the between dimension and they are known as Group Mean Panel Tests. The three Group Mean statistics are extensions of the Phillips and Perron (1998), ρ-statistic and t-statistic and a parametric t-statistic. The null hypothesis for this tests is ρ_i =1 against $\rho_i < 1$.The seven tests are asymptotically distributed as normal as follow:

$$\frac{K_{NT} - \mu\sqrt{N}}{\sqrt{v}} \sim N(0, 1). \tag{20}$$

where K_{NT} is the form of test statistic , μ and v are respectively the average and the variance (see table 2 of Pedroni (1999)).

C PMG (Pesaran,Shin and Smith (2000)):

Pesaran, Shin and Smith (2000) develop a pooled mean group estimator (PMG) for estimating dynamic heterogeneous panel models. The PMG method is an intermediate case between the averaging and pooling methods of estimation. The PMG method restricts the long-run coefficients to be equal over the cross-section, but allows for the short-run coefficients and error variances to differ across group on the cross-section. We obtain pooled long-run coefficients and averaged short run dynamics as an indication of mean reversion. The PMG is based on an autoregressive distributive lag (p, q,. . . ,q) model:

$$y_{it} = \sum_{j=1}^{p} \lambda_{ij} y_{it-j} + \sum_{j=0}^{q} \delta_{ij}^{'} x_{it-j} + \mu_i + \varepsilon_{it}. \tag{21}$$

where X$_{it}$ (K×1) is the vector of explanatory variables for group i, μ_i represents the fixed effects, the coefficients of the lagged dependent variables (λ_{ij}) are scalars and (δ_{ij}) are (K×1) coefficients vectors. Equation (21) can be re-parameterised as:

$$\Delta y_{it} = \phi_i y_{it-1} + \beta_i^{'} x_{it} + \sum_{j=1}^{p-1} \lambda_{ij}^{*} \Delta y_{it-j} + \sum_{j=0}^{q-1} \delta_{ij}^{*} \Delta x_{it-j} + \mu_i + \varepsilon_{it}. \tag{22}$$

where $\phi_i = -(1 - \sum_{j=1}^{P} \lambda_{ij}), \beta_i = \sum_{j=0}^{q} \delta_{ij}^{'}, \lambda_{ij}^{*} = - \sum_{m=j+1}^{p} \lambda_{ij}$ and $\delta_{ij}^{*} - \sum_{m=j+1}^{q} \delta_{im}$.

Firstly, we assume that the residuals in equation (22) are iid, with zero mean, variance greater than zero and finite fourth moments. Secondly the roots of equation (22) must be outside the unit circle. This assumption ensures that $\phi_i < 0$ and hence there exists a long-run relationship between y_{it} and x_{it} defined by:

$$y_{it} = -(\frac{\beta_i^{'}}{\phi_i}) x_{it} + \eta_{it}. \tag{23}$$

The long-run homogeneous coefficient is equal to $\theta = \theta_1 = -(\frac{\beta_i^{'}}{\phi_i})$, which is the same across groups. The PMGE uses a maximum likelihood approach to estimate the model and a Newton-Raphson algorithm. The lag length can be determined using the Akaike Information Criteria.

D FMOLS Mean Group Panel Estimator (Pedroni 2001)

Pedroni's estimator is an average-based estimator defined as the average of the conventional panel FMOLS estimator. The estimation involves five steps from the following model:

$$y_{it} = \alpha_i + x_{it}^{'}\beta + u_{it} \text{ i=1,....,N, t=1,....,T.} \tag{24}$$

Step 1: The data transformation are:

$$y_{it}^* = (\ y_{it} - \overline{y_i}) \text{ and } x_{it}^* = (x_{it} - \overline{x_i}) \text{ where } \overline{y_i} = \frac{1}{N}\sum_{t=1}^{T} y_{it} \text{ and } \overline{x_i} = \frac{1}{N}\sum_{t=1}^{T} x_{it}^{'}$$

Step 2: We estimate equation (24) using the transformed data. Let $\{u_{it}\}$ the estimated residuals and ε_{it} =$x_{it}^* - x_{it-1}^*$ and denote Ω and Δ two estimators of the long-run covariance and the one side long-run covariance martrices of w_{it} =$(u_{it}, \varepsilon_{it}^{'})$.

Step 3: We applies the following transformation:

$$y_{it}^{+} = y_{it}^{*} - \widehat{\Omega_{u\varepsilon}}\widehat{\Omega_{\varepsilon}}^{-1}\widehat{\Omega_{\varepsilon u}} \text{ and } \widehat{\Delta_{\varepsilon u}}^{+} = \widehat{\Delta_{\varepsilon u} - \Delta_{\varepsilon}\ \Omega_{\varepsilon}}^{-1}\widehat{\Delta_{u\varepsilon}}.$$

Step 4: The FMOLS estimator is given by:

$$\widehat{\beta}_{FMOLS_i} = \left[\sum_{i=1}^{T} x_{it}^{*}x_{it}^{*'}\right]^{-1}\left[\sum_{i=1}^{T} x_{it}^{*}y_{it}^{+} - T\widehat{\Delta_{\varepsilon u}}^{+}\right]. \tag{25}$$

Step 5: The ¨Pedroni between FMOLS estimator is the average of the FMOLS estimator (25) computed for each individual, that is:

$$\widehat{\beta}_B = N^{-1}\sum_{i=1}^{N}\widehat{\beta}_{FMOLS_i}. \tag{26}$$

The t-ratio is defined as the average of the t-ratios computed for each individuals of the panel:

$$\widehat{t}_{\widehat{\beta}_B} = N^{-1/2}\sum_{i=1}^{N} t_{\widehat{\beta}_{FMOLS_i}}. \tag{27}$$

E DOLS Mean Group Panel Estimator (Pedroni 2001)

Pedroni (2001) proposed an estimator based on the average of the panel DOLS estimator **"Group Mean DOLS"** that we can obtain from the following regression:

$$y_{it} = \alpha_i + \beta_i x_{it} + \sum_{k=-K_i}^{K_i}\gamma_{ik}\Delta x_{it-k} + u_{it}^{*}. \tag{28}$$

We construct the Group- Mean DOLS estimator as :

$$\widehat{\beta}_{GD}^{*} = \left[N^{-1}\sum_{i=1}^{N}(\sum_{t=1}^{T} Z_{it}Z_{it}^{'})^{-1}(\sum_{t=1}^{T} Z_{it}\widetilde{y}_{it})\right]. \tag{29}$$

where Z_{it} is the 2×(K+1)×1 vector of regressors and $Z_{it} = (x_{it} - \overline{x_i}, \Delta x_{it-k}, ..., \Delta x_{it+k})$.

However, Group Mean DOLS estimator can be constructed by applying the conventional DOLS estimator to the ith member of the panel as follows:

$$\widehat{\beta}^{*}_{GD} = \frac{1}{N}\sum_{i=1}^{N}\widehat{\beta}^{*}_{Di}. \tag{30}$$

Where $\widehat{\beta}^{*}_{Di}$ is the conventional DOLS estimator applied to the ith member and $\sigma_i^2 = \lim_{T\longrightarrow\infty} E\left[T^{-1}(\sum_{t=\&}^{T}\widehat{u}^{*}_{it})^2\right]$ the long-run variance of the residuals from the DOLS regression (28). The associated t-statistic for the between-dimension estimator can be constructed as:

$$\widehat{t}_{\widehat{\beta}^{*}_{GD}} = N^{-1/2}\sum_{i=1}^{N} t_{\widehat{\beta}^{*}_{Di}}. \tag{31}$$

where:

$$t_{\widehat{\beta}^{*}_{Di}} = (\widehat{\beta}^{*}_{Di} - \beta_0)(\widehat{\sigma}_i^{-2}\sum_{t=1}^{T}(x_{it} - \overline{x_i})^2)^{1/2}. \tag{32}$$