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Reassessing the asymmetries and rigidities in the interest rate pass through process: A hidden co-integration approach

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Επανεξετάζοντας τις δυσκαμψίες και την ασύμμετρη συμπεριφορά στην διαδικασία διαμόρφωσης των τραπεζικών επιτοκίων: Μια προσέγγιση κρυμμένης συν-ολοκλήρωσης

Γιάννης Παναγόπουλος και Αριστοτέλης Σπηλιώτης

ΠΕΡΙΛΗΨΗ

Το συγκεκριμένο άρθρο έχει ως σκοπό να διερευνήσει την ύπαρξη δυσκαμψίας και συμμετρίας ή ασυμμετρίας σε ότι αφορά την άσκηση νομισματικής πολιτικής μέσω των επιτοκίων χονδρικής (wholesale rates) στις πιο μεγάλες και ανεπτυγμένες οικονομίες του κόσμου (G5). Η εξέταση της ύπαρξης των δυο προαναφερθέντων στοιχείων θεωρείται κρίσιμη στην προσπάθεια που κάνουν οι πιο ανεπτυγμένες οικονομίες του κόσμου για μια πιο συντονισμένη και κατ' επέκταση πιο αποτελεσματική νομισματική και πιστωτική πολιτική. Συγκεκριμένα εξετάζεται ο τρόπος, το μέγεθος και η ταχύτητα μετάδοσης των μεταβολών των επιτοκίων χονδρικής (wolesale rates) προς τα επιτόκια λιανικής (retail rates) του τραπεζικού συστήματός τους.

Με βάση τα οικονομετρικά αποτελέσματα, τα οποία παρήχθησαν με την χρήση της οικονομετρικής μεθόδου της κρυμμένης συν-ολοκλήρωσης (hidden co-integration) γίνεται εμφανές ότι υπάρχει διαφοροποίηση σε ότι αφορά τις δυσκαμψίες αλλά και τις ασυμμετρίες μεταξύ των εξεταζόμενων χωρών στην άσκηση νομισματικής πολιτικής μέσω των επιτοκίων χονδρικής προς το τραπεζικό τους σύστημα. Το γεγονός αυτό μας αφήνει με ένα σαφή και ανοικτό προβληματισμό ότι η όποια ομογενοποίηση του διεθνούς τραπεζικού συστήματος και ειδικότερα των πέντε πιο ανεπτυγμένων οικονομιών του κόσμου (G5) έχει ακόμα αρκετό δρόμο μέχρι να επιτευχθεί.

CONTENTS

ABSTRACT

This paper reassesses the existing asymmetries and rigidities in the interest rate pass through transmission channels, applied in the advanced economies of US, UK, Canada, Japan and Euro zone (G5). The Crouching Error Correction Model econometric methodology is applied. This method allows us to distinguish the existing asymmetries, based on: first, the speeds of reaction, and second, the time needed for pass through completeness of the asymmetries. Also, it allows for a more thorough consideration in the dynamics of the pass through channels, as data is split in two pieces- the positive and the negative movements (changes). Our empirical findings suggest that: first, a homogenous behaviour (a feedback relationship) for all G5 banking systems is observed regarding the wholesale interest rate policy/vehicle variable choice. However in US and Canada the monetary policy targeting should rather focus more directly on the money market (MM) rates transmission channel instead of the central bank (CB) rates one for efficiency reasons. Second, a non-homogenous price rigid and asymmetric behaviour is found regarding the G5 loan-deposit markets. The empirical distinguishing and accurate measurement of the different aspects of the pass through interest rate process improves our understanding of the nature of the process and perhaps more importantly, can help us to upgrade the practical efficiency in conducting monetary policy actions in a country by country and in a G5 (coordinated) level, as well.

JEL Classification: E52, C22.

Keywords: Interest rates pass through, hidden co-integration, CECM

1. Introduction

The interest rate pass through (PT) process, from the wholesale to the retail rates, is one of the most crucial processes initiated by every central bank (CB) for achieving its monetary policy goals. These goals are often related to price stability (e.g. applying an anti-inflationary policy) and to real economic activity (e.g. smoothing the business cycles). A quick and full PT of wholesale interest rates to retail bank interest rates strengthens monetary policy transmission (Bondt, 2002) and thus may affect price stability (Bondt, 2005). For the latter goal, any change in the CB policy rate is meant to be transmitted to retail interest rates, ultimately influencing consumer and business lending rates and, therefore, aggregate domestic demand and economic activity.

In this paper we are looking for the existence of any asymmetries and/or rigidities and their main "features" related to the PT transmission process from the wholesale interest rates to the retail rates. The empirical investigation focuses on the advanced economies of US, UK, Canada, Japan and Euro zone (G5, hereafter). Possible asymmetries can be related to two important factors: first, the differences between the speed of adjustment (speed of reaction) of the retail rate to the wholesale rate changes and, second, the differences between the reformulated adjustments lag operators, i.e. the degree of PT completeness of the retail rate to wholesale rate changes. Additionally, we look for the degree of long-run interest rate (positive and negative) PT rigidities or sluggishness. For deriving the aforementioned factors, we employ a symmetric/asymmetric Error Correction (EC) approach, developed by Granger and Yoon (2002) known as the 'hidden co-integration' approach which, in its dynamic representation, leads to the Crouching Error Correction Model (*CECM*).

Our empirical finding could be summarised as follows: first, a homogenous behaviour (a *feedback* relationship) for all G5 banking systems is observed regarding the wholesale interest rate policy/vehicle variable choice. Also, it is suggested that in the US and Canada the monetary policy targeting should rather focus (for efficiency reasons) more directly on the MM rates transmission channel instead of the CB rates one. Second, a non-homogenous price rigid and asymmetric behaviour was revealed regarding the G5 loan and deposit markets. The distinguishing and the accurate measurement of the different aspects of the PT interest rate process i.e. the instant PT effect, the speed and/or the time of the adjustment, the long run elasticity (degree of rigidity) and or the combination of these elements enriches our understanding on the entire PT interest rate process. Finally, it helps us to improve our practical efficiency in conducting monetary policy actions in a country and at G5 (coordinated) level as well.

The structure of the paper is as follows: first, in section 2, we briefly discuss the theoretical framework and the interest rates PT modelling process that is inferred; in section 3, data and the empirical results of the CECMs on a country-to-country basis are presented; finally, in section 4, we conclude.

2. Interest rate PT process and the crouching error correction model

2.1 The theoretical framework of price rigidities and asymmetries

In the banking sector, the existence of any price rigidity ("price-setting" retail decisions) is related to the decision taken by the bank's managers regarding the retail interest rates choices, which, in the long run, are considered as profit maximising. As Cottarelli and Kourelis (1994) argue, a profit-maximising bank will only change the lending rate if the adjustment costs[1] are lower than the costs of keeping lending rates unchanged. The cost of maintaining non-equilibrium rates is positively related to the elasticity of the demand for bank loans. The demand for bank loans is less elastic in markets that have fewer competitors, higher barriers to entry or no alternative sources of finance, including foreign capital. Also, bank managers will

[1] Apart from the *Adjustment costs* theory, a number of relative *Cost theories* have been developed in order to give some theoretical reasoning on the retail interest rates sluggishness phenomenon observed. For example, the *Agency costs* theory of Stiglitz-Weiss (1981), the *Switching costs* theory of Klemperer (1987) and Lowe and Rohling (1992) and the R*isk sharing* framework of Fried and Howitt (1980).

not adjust their loan rates if they feel that increases/decreases in the money market rates are temporal. So, the interest rate rigidity or sluggishness is related to structural and/or institutional aspects of the financial market, i.e. the concentration level (degree of oligopoly) of the retail market as well as the temporal or non-temporal nature of wholesale interest rate changes.

Within the PT framework, apart from the ‘rigidity’ issue, the aspect of the observed differences in the speed of transmission from the wholesale to the retail interest rates must be considered (the issue of symmetric/asymmetric transmission). This issue is basically connected to the bank manager’s willingness for transferring to their clients (retail rates) any wholesale rate changes. Such speed is possibly affected by the degree of banks’ retail market competitiveness. More specifically, in a competitive banking environment, the deposit rates are expected to be reluctantly raised by the banks, responding this way to the wholesale rates increase. At least a similar speed of deposit rates’ adjustment is expected, regarding the decrease of the deposit rates, when the wholesale rates are falling, when perfect competition exists[2]. Consequently, the less competitive the deposit market is, the higher the inequality between the two speeds of deposit rate adjustment is expected to be. In a competitive loan market, the positive and negative speed of adjustment is expected to be almost equal. As in the previous case, in a less competitive loan market, the two speeds of adjustment are expected to differ. More specifically, any wholesale rate decline will be followed by a reluctant and sluggish decrease in loan rates and any wholesale rate rise will be followed by a quick loan rate increase. Such behaviour is theoretically consistent, regarding the deposit market, with the Hannan and Berger (1991) adverse *Customer Reaction Hypothesis*, and with their *Bank’s Collusive Hypothesis*[3], regarding the loan market.[4]

Also, the issue of the positive and/or negative mean adjustment lag operator(s) from the

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[2] As Neuwark and Sharpe (1992) indicate, asymmetry in a market is less pronounced when competition is fierce.

[3] For an analytical presentation of the C*ollusive Pricing Arrangement Hypothesis* and the adverse C*ustomer Reaction Hypothesis* see Hannan and Berger (1991).

[4] Additionally, a *symmetric* adjustment (behavior) of both the retail interest rates to any wholesale rate changes should be considered as being in favor of a bank’s clients (depositors and/or borrowers) and thus can be

wholesale to retail rates emerges. The lag operator tells us how much time (e.g. weeks, months, etc.) it takes for a given change, positive and/or negative, in the wholesale rates to be *fully* transmitted to the corresponding retail rates. Therefore, if it takes more time to *fully* transmit an increase than a decrease of the wholesale rates to the retail rates then a positive asymmetry exists while negative asymmetry exists in the opposite case.

2.2 The Error Correction Representation (pass through) Model

An interest rate PT model tries to mathematically express the way in which wholesale (central and/or interbank money market) rates are transmitted to retail (deposit and loan) rates. Such PT equations usually take the following long run (equ.1a) and dynamic EC (equ.1b) algebraic form:

$$r_{r,t} = c + \phi * r_{w,t} + e_t \qquad (1a)$$

and

$$\Delta r_{r,t} = c + \sum_{j=1}^{k} \mu_j * \Delta r_{r,t-j} + \sum_{i=0}^{n} \pi_i * \Delta r_{w,t-i} + \theta * e_{t-1} + u_t \qquad (1b)$$

where: $r_{r,t}$ stands for the different loan and deposit rates (e.g. the prime loan rates, the time deposit rates, the certificate of deposits rates, etc.) and $r_{w,t}$ stands for the central bank or money market rates (e.g. the overnight rate, the three-month money market rate, the discount rate, etc.), the Greek letter Δ stands for first difference operator and e_{t-1} stands for the EC term.

The aforementioned dynamic EC model (ECM hereafter) can be further extended to an *asymmetric* ECM (Granger and Lee, 1989). In order for asymmetries to be captured by the model, the co-integration residuals and first differences on the interest rates (r's) can be decomposed into positive and negative values. So, the dynamic interest rates PT model (equ. 1b) can be re-written as:

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incorporated into the theoretical framework of the adverse *Customer Reaction Hypothesis*.

$$\Delta r_{r,t} = \delta_0 + \sum_{j=1}^{k1} \delta_{ir}^{-} \Delta r_{r,t-j}^{-} + \sum_{i=0}^{k2} \delta_{iw}^{-} \Delta r_{w,t-i}^{-} + \sum_{j=1}^{k3} \delta_{ir}^{+} \Delta r_{r,t-j}^{+} + \sum_{i=0}^{k4} \delta_{iw}^{+} \Delta r_{w,t-i}^{+} + \theta^{+} e_{t-1}^{+} + \theta^{-} e_{t-1}^{-} + \eta_t \qquad (2a)$$

Further expressed as:

$$\Delta r_{r,t} = \delta_0 + \sum_{j=1}^{k1} \delta_{ir}^{-} \Delta r_{r,t-j}^{-} + \sum_{i=0}^{k2} \delta_{iw}^{-} \Delta r_{w,t-i}^{-} + \sum_{j=1}^{k3} \delta_{ir}^{+} \Delta r_{r,t-j}^{+} + \sum_{i=0}^{k4} \delta_{iw}^{+} \Delta r_{w,t-i}^{+} + \theta^{-} (r_r - \phi\, r_w)_{t-1}^{-} +$$

$$+ \theta^{+} (r_r - \phi\, r_w)_{t-1}^{+} + \eta_t \qquad (2b)$$

Additionally to the aforementioned *asymmetric* ECM (equ. 2b) we can comment that when cumulative positive and negative subcomponents of any pair of two interest rates ($r_{r,t}$, $r_{w,t}$) are ex-ante used, then we do not have just one (common) long-run PT coefficient (ϕ) as it appears in equation 2b but, instead, we can have two long-run PT coefficients, i.e. ϕ^{+}, ϕ^{-} (see equation 3). This fact has two important implications regarding the symmetry tests: first, an additional symmetry test on long run rigidities can be optionally implemented, i.e. if $\phi^{+} = \phi^{-}$ and, second, the formulation of the two mean adjustment lag operators defined as: $\gamma^{+} = (\phi^{+} - \delta_{0w}^{+}) / \theta^{+}$ and $\gamma^{-} = (\phi^{-} - \delta_{0w}^{-}) / \theta^{-}$, respectively. The mean adjustment lag effect tells us how much time (number of months, weeks, etc.) it takes for a positive and/or negative change in the wholesale rates to be *fully* transmitted to the corresponding retail rates. In the existing literature (e.g. Chong, Liu and Shrestha, 2006) the numerator of the mean adjustment lag operator contains the value of one, i.e. that a long-run PT elasticity equals to one minus an instant dynamic short-run effect (e.g. 1-$\delta_{wo}^{\pm}$, in equ. 2b). However, in our reformulated representation, the value of the long-run PT elasticity is not pre-assumed to be equal to one (e.g. $\phi \neq 1$, in equation 2 and/or $\phi^{\pm} \neq 1$, in equation 3). This implies that a long-run complete PT is not pre-determined and therefore the nominator of the adjustment lag operator is now defined as: $\phi - \delta_{wo}^{\pm}$, in equation 2 and/or $\phi^{\pm} - \delta_{wo}^{\pm}$, in equation 3.

Summarising, the *asymmetric* ECM (2b equation) allows for: a) a speed of adjustment test, i.e. if $\theta^{+} = \theta^{-}$ (a long-run symmetry test), b) an instant PT dynamic test, i.e. if $\delta_{0w}^{+} = \delta_{0w}^{-}$ (a short-run symmetry test) and c) a mean adjustment lag test, i.e. if $\gamma^{+} = \gamma^{-}$, with $\gamma^{+} = (\phi - \delta_{0w}^{+}) / \theta^{+}$ and $\gamma^{-} = (\phi - \delta_{0w}^{-}) / \theta^{-}$, respectively[5] (a second long-run symmetry test)[6].

2.3 The Crouching Error Correction Model

From the bi-variate PT literature[7], the *asymmetric* Error Correction Model (AECM)[8], the LSE–Hendry general-to-specific Model (GETS)[9] and the Threshold Error Correction Model (TECM), are some of the main econometric methodologies for testing asymmetries. More specifically, Hofmann and Mizen, 2004 and Chong, Liu and Shrestha, 2006, implemented the AECM approach for testing interest rate PT asymmetries. On the other hand, Sander and Kleimeier, 2004, Payne, 2007, Payne and Waters, 2008, Wang and Nguyen Thi, 2010 and Becker, Osborn and Yildirim, 2012, implemented some TECM (mainly a TAR and/or a Momentum TAR type of approach)[10] on interest rate PT asymmetries[11]. Finally, Rao and Rao, 2008, implemented the GETS approach for testing PT asymmetries on the gasoline price adjustments.

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[5] The mean adjustment lag test for equation 3 will be: $\gamma^{+} = \gamma^{-}$, with $\gamma^{+} = (\phi^{+} - \delta_{0w}^{+}) / \theta^{+}$ and $\gamma^{-} = (\phi^{-} - \delta_{0w}^{-}) / \theta^{-}$, respectively.

[6] In theory, the two mean adjustment lag operators represent the time needed for the interest rate *PT completeness* to be fulfilled. This simply means, the time needed for the *remaining* (apart from the instant) positive and/or negative wholesale rates' change to be completely transmitted to the corresponding retail rates.

[7] For a complete survey on econometric models of asymmetric price transmission (PT), see Frey and Manera (2007).

[8] In fact, it was Von Cramon-Taubadel and Loy (1997) and Von Cramon-Taubadel (1998) who actually introduced the *symmetric/asymmetric* ECM approach through an *ex ante* disagreggation of the data.

[9] The GETS methodology was introduced by Hendry, 1987; Hendry and Krolzig, 2005. This methodology was substantially evolved by Bachmeier and Griffin (2003) and Rao and Rao (2008).

[10] Enders and Granger (1998) and Enders and Siklos (2001) introduced a subcategory of Threshold Models, often used in the interest rates PT literature, called the Threshold Autoregressive Model (TAR) and the Momentum Autoregressive Model (MTAR), respectively.

[11] Alternatively, there are also some qualitative response models which examine the issue of PT asymmetries using probit methodology (see Dueker, 2000). Such models often contain some Markov Regime Switching processes.

In the same symmetric/asymmetric framework lies the CECM, actually derived from the Granger and Yoon's (2002)[12] hidden cointegration approach. This model is more flexible than the TECM, as it is not limited to two (or more) regimes and we can investigate all possible combinations of cointegration between data components. Additionally, it looks closer to the AECM & GETS approaches than the TECM, since it initially presupposes an *ex ante* positive and negative disaggregation of the data and then a cumulative aggregation of these two parts in the Data Generation Process (DGP). Consequently, the hidden cointegration approach allows for distinct cointegrating relationships between subcomponents (positive and negative) of two time series even when cointegration between them is not identified at the aggregate level. This data flexibility might offer: a) better insight into the asymmetry, both in the long- run and short-run level and b) the implementation of a CECM.

As Honarvar (2009) points out, one of the advantages of the hidden cointegration approach over, for instance, the standard asymmetric ECMs in the literature, is that it investigates all possible combinations of cointegration between data components. The CECM methodology contains all the advantages of the LSE–Hendry General to Specific (GETS) methodology (that we can simultaneously estimate the short-run and long–run coefficients in the same dynamic model and that we can test for the existence of any asymmetric effects) and additionally allows for cumulative, positive and/or negative, long-run estimators to be embedded in its structure. This last advantage allows for: a) a differentiation of the long-run rigidity in the upward and/or downward PT channel and b) the derivation of more accurate estimates of the positive and/or negative mean adjustment lag operators.

Furthermore, a careful investigation of PT dynamics must consider whether a retail interest rate which adjusts quickly to something less than a complete PT is preferable to a retail interest rate which adjusts slowly to a complete PT. In terms of market efficiency it is not

[12] For an analytical presentation of CECM methodology, see Granger and Yoon (2002). Alexakis et al (2013) and Honarvar (2009) are two interesting applications of the methodology.

straightforward to judge whether one or the other scenario is preferable. In order to gauge the combined impact of the speed of adjustment and the degree of long-run PT, we multiply the two coefficients to obtain a "relative adjustment" measure (Sorensen and Werner, 2006). However, in our paper, due to the discrimination between negative and positive cumulative changes in interest rates data, we can further extend this approach to a negative and positive "relative adjustment" measurement. Thus, we can create a new asymmetry measurement, the 'total asymmetry' (TS) score, where the TS score is derived from the following ratio: $TS = (\phi^{+} * \theta^{+}) / (\phi^{-} * \theta^{-})$. If TS values are close to unity, then 'total' symmetry emerges. On the other hand, if TS values are substantially different from unity, then we have negative or positive 'total' asymmetry. We can further argue that the TS score value can provide us with some extra information regarding to which specific wholesale PT vehicle/tool rate 'causes' the most symmetric results to the retail rate markets.

In practical terms, this is inferred by comparing the TS values (the ratio of the 'total' positive and negative "relative adjustment" effects) derived from the two wholesale interest rates PT channels, the CB and/or the MM one. Therefore, a comparative view on the TS scores (values), among the PT of different pairs of wholesale and retail interest rates, gives the relative magnitude of their 'total' symmetric or asymmetric behaviour. The TS score which is closer to the value of unity indicates which wholesale channel behaves in the most symmetric (and therefore more efficient) way.

Finally, before we proceed to the empirical part of the interest rate PT, we should clarify which wholesale rate should be chosen to 'spill over' to the retail rates. In most cases, the literature neglects the crucial question of whether CB policy rates (e.g., the discount rate, the marginal lending facility rate, etc.) or the interbank MM rates (e.g., the overnight rate) should be selected as the PT policy variable to the retail rates. The selection of the most appropriate PT 'vehicle' answers questions on which monetary policy channel is the most effective one. It reveals if the PT process is directly transmitted or not. For example, is there a direct link between CB policy rates and retail deposit/loan rates or does it pass first through the interbank MM rates channel/market?

3. Data and empirical results

3.1 Data

We use monthly data of the G5 economies (1980:1 to 2011:11) from the *Financial Statistics* of the International Monetary Fund (IMF). For the US, the discount rate and the federal fund rate are used for proxying the CB (i_{CB}) and the MM (i_{mm}) interest rates, respectively. The three-month Certificates of Deposit (CD) and the prime loan rate are used for proxying the retail rates (deposit and loans) (i_L and i_D, respectively). Regarding Canada, the CB policy rate and the overnight MM rate are used for the CB (i_{CB}) and the MM (i_{mm}) interest rates, respectively. The 90-day fixed deposit rate (i_D) and the prime loan rate (i_L) are proxying the corresponding retail rates. Turning to the UK, the data information is sourced accordingly: the CB policy rate (i_{CB}), the overnight interbank rate (i_{mm}) and the lending (bank clearing) rate (i_L) are provided by the IMF *Financial Statistics* while the "three-month Sterling Certificates of Deposit interest rate", which is used as proxy for the deposit rate (i_D), is derived from the Bank of England *Statistics*. Turning now to the case of Japan, we have all the rates from the IMF *Financial Statistics*: the discount rate (i_{CB}), the call money rate (i_{mm}), the deposit rate (i_D) and the lending rate (i_L). Finally, in the case of the Eurozone, the marginal lending facility rate is used for proxying the CB interest rate (i_{CB}) and the interbank three-month maturity rate is used for proxying the MM (i_{mm}) rate. Both rates are provided by the IMF *Financial Statistics* data set. For the Eurozone's retail rates (deposit and loan), we use data from the *ECB Statistical Data Warehouse* database. More specifically, the lending rate (i_L) we use is the weighted average of four different lending rates[13] while, for the deposit rate (i_D), we use the total deposits for non-financial corporations & households. In contrast with the other four countries, the examined time period for the Eurozone ranges from 2003:1 to 2011:11.

For all the aforementioned interest rates variables, we split the observations into positive and negative movements and then accumulate them at each time *t*.

3.2 Empirical Results

First of all, we test if the series are integrated with the order of one (Table 1) and then we further search for the existence of any hidden cointegrating pairs between wholesale and retail series.

From Table 1 it is obvious that most of the examined series are indeed integrated of order one[14] and thus we proceed to the implementation of the hidden co-integration technique among cumulative positive and negative changes of wholesale and retail data components.

In empirical terms, first we test for the existence of hidden co-integrating vectors among different wholesale, CB and MM, interest rates and, then, we apply regressions on the long-run PT wholesale/retail interest rate pairs[15].

However, regardless of the long run hidden co-integrating test results (the johansen's results), we proceed to the next stage of the hidden cointegration estimating methodology with a direct implementation of the CECM methodology. We do this because in some cases co-integration exists without being clearly revealed by the pair wise Johansen tests results. The selected generalised CECM is:

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[13] These rates are: the loans for non-financial corporations, up to 1 year (L1), up to 1 year and over 1 million euros (L2), over 5 years (L3) and the loans for consumption, from 1 to 5 years (L4).

[14] Few exceptions exist in the Eurozone case. The cumulative sum of negative components of CB (r^{-}_{CB}), the cumulative sum of positive components of Deposits (r^{+}_{DE}) and the cumulative sum of positive components of Loans (r^{+}_{LO}) are not found to be integrated of order I (1).

[15]. The pair wise Johansen tests results (*Eigen values* & T*race*) and the long run estimators of the hidden cointegration regressions are available upon request.

$$\Delta i_{r,t} = a + \sum_{i=0}^{k1}\delta_{iw}^{-}\Delta i_{w,t-i}^{-} + \sum_{i=1}^{k2}\delta_{ir}^{-}\Delta i_{r,t-i}^{-} + \sum_{i=0}^{k3}\delta_{iw}^{+}\Delta i_{w,t-i}^{+} + \sum_{i=1}^{k4}\delta_{ir}^{+}\Delta i_{r,t-i}^{+} + \theta^{+}(i_{r,t-1}^{+} - \varphi^{+} i_{w,t-1}^{+}) +$$

$$+ \theta^{-}(i_{r,t-1}^{-} - \phi^{-} i_{w,t-1}^{-}) + \eta_t \qquad (3)$$

Where: $i_{r,t}$ stands for the different loan and deposit rates (e.g. the prime loan rate, the time deposit rate, the certificate of deposits rate, etc.) and $i_{w,t}$ stands for the central bank or money market rates (e.g. the overnight rate, the three-month money market rate, the discount rate, etc.), the Greek letter Δ stands for first difference operator and η_t stands for the error term.

This aforementioned dynamic model selection is qualified because it encompasses all the possible long- run hidden cointegration PT options[16].

The presentation of the empirical CECM PT results, on a country-by-country basis, constitutes a variety of α*symmetry and rigidity tests*. More specifically, *asymmetry tests* regarding the positive/negative time speed of adjustments (θ^{+}, θ^{-}). Furthermore, some new *asymmetry tests* are estimated for the first time. For instance, the difference of the two mean (reformulated) adjustment lags ($\gamma^{+} = (\phi^{+} - \delta_{w0}^{+})/\theta^{+}$, $\gamma^{-} = (\phi^{-} - \delta_{w0}^{-})/\theta^{-}$) is now computed in order to determine the degree of symmetry/asymmetry of the PT completeness, the so-called ψ-score $(\psi = \gamma^{+} - \gamma^{-})$[17]. Also, the two hypotheses of positive and negative long- run PT rigidities ($\phi^{\pm} = 1$) are tested. Finally, we compute the TS-score, the '*total symmetry*' ratio[18].

[16] All CECM have been estimated with Non-Linear Least Squares (NLLS). Note that OLS and NLLS estimates give similar results. We thus present here the NLLS estimates in order to conserve space.

[17] *Symmetry*, regarding the PT completeness, will imply that $\psi \leq |2|$ (months). In case where $|2| \leq \psi \leq |4|$ (months), we can accept the existence of *weak asymmetry* on the issue of PT completeness. Negative weak asymmetry exists when negative value is the derived result and positive weak asymmetry exists when the derived result is positive. In case where $\psi \geq |4|$ (months), we can admit the existence of a *strong (negative or positive) asymmetry* on the issue of PT completeness.

[18] We define as *total symmetry* the case when $[0.80 - 1.0] \cong TS \cong [1.0 - 1.20]$. We accept the existence of (positive or negative) *weak total asymmetry* when $[0.50 - 0.80] \cong TS \cong [1.20 - 1.50]$. Finally, *strong*

The US Banking System (Table 2)

We examine both CB and MM interest rates in playing the role of the vehicle/target monetary policy variable (tool) in the PT process from the wholesale to the retail rates[19]. First we present the statistical results related to questions such as, how much is the instant (positive and negative) PT effect in the transmission process? Is it a complete process? If not, how long it takes to be completed?

The PT adjustment process in both channels (positive and negative) is approximated by the four following model's parameters (see equation 3):

$\delta^{\pm}_{w0}$ parameters, which are mirroring the instant (positive and negative) PT effect,

$\phi^{\pm}$ parameters, which account for the (positive and negative) long run elasticity,

$\theta^{\pm}$ parameters, (error correction terms) which give a measure of the speed of the (positive and negative) long run adjustment process and

$\gamma^{\pm}$ parameters, which contains information on the required time the remaining value needs to transmitted i.e. the value left after the instant (positive and negative) PT effect of the process (($\gamma^{+} = (\phi^{+} - \delta^{+}_{w0}) / \theta^{+}$, $\gamma^{-} = (\phi^{-} - \delta^{-}_{w0}) / \theta^{-}$)).

The strong statistical significance of $\theta^{\pm}$ parameters (error correction terms) simply denotes that the PT transition process exist. The values of $\theta^{\pm}$ coefficients measure the speed that this adjustment process takes place. In US data it is clear that the speed of the adjustment process in the deposits' market is match higher than in the loan markets (more than triple).

Looking now at the values of $\delta^{\pm}_{w0}$ coefficients, in the negative channel, the instant PT effect ranges from 59% to 89% in the deposit market, while in the loan market this effect accounts for 33%. In the positive channel, the equivalent figures range from 59% to 1.22%

(negative or positive) *asymmetry* can be accepted when $0.50 \leq TS \geq 1.50$.

[19] A "Granger causal" relationship between the two wholesale interest rates (CB and MM) was tested in USA and

(overshooting) in the deposit market and from 34% to 86% in the loan market.

Going further and looking at the values of $\phi^{\pm}$ coefficients (long run elasticities) we easily observe that all of them are close to unity. This means that in the long run the whole changes (negative or positive) in the wholesale rates are totally transmitted to the retail rates[20]. Looking at the $\gamma^{\pm}$ (calibrated) values we see that the necessary time needed for the remaining adjustment process to be completed takes 0.18 το 1.53 months, in the deposit market while it takes 0.5 to 12.0 months in the loan market.

Turning now to the asymmetry tests, first we compare the $\theta^{\pm}$ values (the measure of the speed of adjustment) in order to check for the existence of speed symmetry. Second, by comparing the $\psi = \gamma^{+} - \gamma^{-}$ (calibrated) values we check for symmetry regarding the time needed for the remaining (after the instant effect) positive or negative wholesale rates' change to be completely transmitted to the corresponding retail rates.

In the US data case, regarding the speed symmetry test, positive asymmetry was found as all θ^{+} are higher than θ^{-} i.e. $\theta^{-} < \theta^{+}$. Also, looking at the results of the second symmetry test (ψ values), we found that time adjustment symmetry exists in the deposit market and strong negative asymmetry appears in the loan market.

The combined statistical results gives a clear indication that US data, in the loan market, fits in the Bank's Collusive Hypothesis (BCH) framework i.e. an increase in the wholesale rate is faster transmitted (θ^{-}, θ^{+}) and completed (γ^{-}, γ^{+}) to the retail rates. In economic terms that imply that any increases in the CB or MM rates would be absorbed by the retail loan markets faster and more completed than any decreases. In the deposit markets the data (symmetry or positive asymmetry results) signals a rather Adverse Customer Reaction

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a strong *feedback* relationship was found, as expected.

[20] On the issue of the rigidity existence, regarding the long-run PT estimators, the implemented (Wald) tests accept the null hypothesis of perfect PT completeness in all cases (with the exception of the MM+ vs. CB+ relationship: x^2 =6.23).

Hypothesis (ACRH) behavior.

Finally, looking at the TS-score (calibrated) values, we have a clear preference in the use of the MM rate (than the CB rate), as it gives more symmetric results with respect to the two retail rates. So, a policy targeting more directly on the MM rates may function more effectively in the PT process.

The UK Banking System (Table 3)

As in the US case, a *feedback* causal relationship exists between the two UK wholesale rates (CB and MM). Again the strong statistical significance of $\theta^{\pm}$ parameters found (error correction terms) denotes that the PT transition process exists. In the UK case, opposite to the US one, the speed of the adjustment process in the loan market is match higher than in the deposit one (almost double).

In the UK case the instant PT effects, as they are represented through the $\delta_{w0}^{\pm}$ values, signify a strong preference to the CB channel instead of the MM one. The $\delta_{w0}^{\pm}$ values of the CB channel are very close to unity. This in turn implies that any change in the CB rate (positive or negative) is almost instantly and entirely PT to the retail interest rates in the loan and deposit markets. The strong and close to unity value of $\delta_{w0}^{\pm}$ parameters minimize the importance of the $\gamma^{\pm}$ parameters as there is no any remaining value left to be transmitted from the change of the CB rate to the retail interest rates, after the instant PT effect.

Looking now at the values of $\phi^{\pm}$ coefficients (long run PT elasticities or rigidities) we easily observe that all of them are close to unity.[21] As far as it concerns $\gamma^{\pm}$ (calibrated) values we can see that all of them are negligible magnitudes due to the high values of $\delta_{w0}^{\pm}$ (instant PT

[21] On the issue of the rigidity existence, the Wald tests accept the null hypothesis of perfect PT completeness in the deposit markets but it is rejected in the loan markets. However, even in the loan markets the long run positive and negative PT elesticities range from 0.90 to 1.01.

effects, see Table 3c). Turning now to the asymmetry tests, the UK picture is quite clear. It gave us very symmetric results in both aspects (time and speed of adjustments). More specifically, all null hypotheses examined regarding speed symmetry ($\theta^{-} = \theta^{+}$) are verified. The same symmetric picture emerges regarding the time needed for the remaining (after the instant effect) positive or negative wholesale rates' change to be completely transmitted to the corresponding retail rates.

The aforementioned symmetrical empirical results derived from for the UK loan and deposit data seems to fit in the ACRH behavioral framework. The economic interpretation of this behavior implies that any increases/decreases of the CB or MM rates will be equal proportionally absorbed by both loan and deposit retail markets.

Finally, as far as the total symmetry **(**TS) results concerns, they range from 0.95 to 1.0. This kind of symmetrical results implies that both wholesale PT rates (CB and MM) can equally function as an effective transmission monetary policy channel.

The Canadian Banking System (Table 4)

A feedback relationship exists between the two wholesale rates (CB and MM). Again the strong statistical significance of $\theta^{\pm}$ parameters found (error correction terms) denotes that the PT transition process exists. Similarly to the UK case the instant PT effects, as they are expressed by the $\delta^{\pm}_{w0}$ values, signify a strong preference to the CB channel compared to the MM one. In the Canadian case this preference is also supported by the values of $\theta^{\pm}$ coefficients that measure the speed that this adjustment process. Especially, in the loan market the PT transition process from the CB rates to the retail rates is the quickest. The significance of this channel is emerged by both the speed of the PT adjustment process ($\theta^{\pm}$ coefficients ranges from, 0.31 to 0.45) and the instant PT effect process ($\delta^{\pm}_{w0}$ coefficients ranges from 0.72 to 0.88).

Looking at the values of $\phi^{\pm}$ coefficients (long run PT elasticities or rigidities) we see that in the long run the PT completeness is rather weak. These conclusion is also supported by the Wald tests. As far as the $\gamma^{\pm}$ values concern, we can observe that all of them are more or less negligible thanks to the high values of $\delta_{w0}^{\pm}$ coefficients (instant PT effects), especially in the CB channel.

Turning now to the asymmetry tests, first we compare the $\theta^{\pm}$ values (the measure of the speed of adjustment) in order to check for the existence of speed symmetry. Second, by comparing the $\psi = \gamma^{+} - \gamma^{-}$ (calibrated) values we check for symmetry regarding the time needed for the remaining (after the instant effect) positive or negative wholesale rates' change to be completely transmitted to the corresponding retail rates.

Commencing from the time and/or speed of adjustment (in both loan and deposit markets) symmetry/asymmetry tests, the Canadian banking system looks quite similar to the UK one. Almost all tests gave to us quite symmetrical results. More analytically, regarding the deposit market, the examined time speed of adjustment is symmetric or positively asymmetric depending on the implemented wholesale rate. Particularly, when the CB rate is used as the wholesale PT policy variable, $\theta^{-} = \theta^{+}$. When MM rate is chosen as the policy variable then positively asymmetry was found, $\theta^{-} < \theta^{+}$.

Turning now to the (time) asymmetry test of the PT completeness ($\psi = \gamma^{+} - \gamma^{-}$) in the deposit market, we accept the symmetry hypothesis (ψ : -1.62 months) when the CB rate is the wholesale PT policy variable. When the MM rate is chosen as the wholesale PT policy variable an almost symmetrical result is taken (ψ : -2.21months).

Regarding the loan market tests, symmetric results were found with respect to the examined time speed of adjustment coefficients ($\theta^{-} = \theta^{+}$) for both wholesale PT policy variables. Concerning now, the PT completeness test ($\psi - score$), when the CB policy variable is chosen the results are symmetric (ψ: -0.28 months) while, when the MM rate channel is followed a weak negative asymmetric/symmetric result is produced (ψ: -2.23 months). Obviously, the overall statistical results of the Canadian data fit to the A*CRH* behavioral framework (as in the UK case).

On the issue of the TS-scores when the two wholesale PT vehicle/tool rates are examined against the two retail rates the MM PT channel gave more symmetrical results.

The Japanese Banking System (Table 5)

A *feedback causal* relationship exists between the two wholesale rates (CB and MM). The existence of strong statistical significance of $\theta^{\pm}$ parameters (error correction terms) denotes that the PT process from the wholesale to the retail rates exists. However, the speed of the adjustment of the PT process is very low, regardless of the implemented wholesale rate, in both the loan and the deposit market. Regarding the instant PT effect, very low $\delta_{w0}^{\pm}$ values are also observed. This implies that any change in the wholesale rates takes quite long time to be completely transmitted to the retail rates. This situation is also advocated by the high values of the $\gamma^{\pm}$ parameters found.

Looking now at the $\phi^{\pm}$ coefficients (long run PT elasticities or rigidities) we observe that in the case of the deposit market the $\phi^{\pm}$ values range from 0.61 to 0.89 while, in the loan market they are even lower ranging from 0.47 to 0.67. So we can accept the hypothesis that in the long run the PT completeness process is quite slow (also verified by the implemented Wald tests).

Turning to the asymmetry tests results, regarding the time and the speed of adjustment tests, the Japanese loan market gives clearer evidence than the deposit market. More analytically, in the loan market the speed and the time adjustment tests results fit better to the

BCH behavioral framework, i.e. $\theta^{-} < \theta^{+}$ and $\gamma^{-} > \gamma^{+}$.

In the deposit market when the two wholesale rates, CB and MM, were tried as the PT vehicle/policy variables we got contradictive results. The ACRH behavioral framework is favored when the CB rate is chosen as PT policy variable i.e. $\theta^{-} = \theta^{+}$ (symmetry) and $\psi = \gamma^{+} - \gamma^{-}$= 2.22 months (almost symmetry). On the other hand, the situation is reversed when MM is chosen as PT policy variable. Concerning the speed of adjustment, a negative asymmetry result was found ($\theta^{-} > \theta^{+}$), accompanied by a light positive asymmetry regarding the PT completeness test (ψ =1.26 months). Therefore a BCH behavioral framework is advocated.

On the issue of the TS-score, both the wholesale PT rates give symmetric results with respect to the deposit market (TS : 0.95 for MM and 1.05 for CB). On the other hand, with respect to the loan market, the MM rate produces much more symmetric results than the CB rate does (TS : 1.15 for MM and 4.11 for CB).

The Eurozone Banking System[22] (Table 6)

Again, a feedback *r*elationship was found to exist between the two wholesale rates (CB and MM). Commencing from the $\theta^{\pm}$ values we easily observe that the CB channel operates faster than the MM one in both markets. Additionally, the speed of adjustment of the CB negative channel is higher than the positive one in both, loan and deposit, markets. This is in line with the observed downfall trend of the interest rates in the Eurozone during all the examined period (2003–2011).

On the other hand, very low $\delta_{w0}^{\pm}$ values, ranging from 0.08 to 0.20, are observed regarding the instant PT effect when the CB rate is used. Also, the positive δ_{w0}^{+} values were found statistically insignificant. Opposite results were appeared regarding the MM channel:

[22] We should remind to the reader that data for Euro zone exists only for the period 2003 and after.

relatively higher and statistically significant $\delta_{w0}^{\pm}$ values (0.18 to 0.50), accompanied by lower speed of adjustment $\theta^{\pm}$ parameters (ranging from 0.11 to 0.21).

As far as the long-run PT estimators ($\phi^{\pm}$) concerns, the derived estimators are significantly varying. It ranks from the 88% of PT completeness up to 139% (overshooting) PT completeness. The implemented Wald tests accept the null hypothesis of PT completeness in all cases in the positive channel irrespectively with the wholesale rate applied. On other hand, in the negative channel, rigidities (rejections of the null hypothesis) appeared with the only exception of the MM^- and DE^- PT relationship.

Turning to the asymmetry tests' results and commencing from the Eurozone's deposit market, we can see that it rather fits in the *BCH* behavioral framework. More analytically, the negative asymmetry result, regarding the examined speeds of adjustment ($\theta^- > \theta^+$) and the symmetry result, regarding the PT completeness ($\psi : \gamma^- = \gamma^+$, equals to 1.84 months), comply with a BCH behavior.

Turning now to the Eurozone's loan market, the results consist of much clearer evidence than in the case of the deposit markets. The speed and the time adjustment testing results i.e. $\theta^- > \theta^+$ and $\gamma^- \le \gamma^+$, fit in the *ACRH* framework when both wholesale rates are tested.

On the issue of the TS-scores, commencing from the *loan* market, the MM rate produces more symmetrical results (TS =1.40 stands for MM and TS =0.40 stands for CB, respectively). Concerning the deposit market, the TS-scores cannot be calculated as in a quite a few cases the error correction terms, $\theta^{\pm}$ values, were found wrongly (positively) signed.

4. Conclusion

The aim of this paper is to try to reassess the interest rate PT transmission processes by utilizing all the advantages that the Granger and Yoon Crouching Error Correction Modeling methodology provides. We estimated the short-run and long–run coefficients in the same dynamic model. We tried to statistically distinguish and measure the different components of the existed type of asymmetries and rigidities, allowing for cumulative, positive and/or negative, long-run estimators to be embedded in the structure. This last advantage allows for a differentiation of the long-run rigidity in the upward and/or downward PT channel and the derivation of more accurate estimates of the positive and/or negative mean adjustment lag operators.

Based on the above approach we extracted some interesting information contained in the data. First, a homogenous behaviour (a *feedback* relationship) for all G5 banking systems is observed regarding the wholesale interest rate policy/vehicle variable choice. However, the TS-score analysis suggested that in the cases of the US and Canadian economies the monetary policy targeting should rather focus (for efficiency reasons) more directly on the MM rates transmission channel instead of the CB rates one.

Second, a non-homogenous and asymmetric behaviour was revealed regarding the G5 loan and deposit markets. On a country-to-country basis, the US loan market fits better in a Bank's Collusive Hypothesis behavioral framework while, the deposit market rather fits into the Adverse Customer Reaction Hypothesis. Opposite to the US result, in Eurozone, the CB and MM rates in their reaction with the retail loan interest rates fit in the Adverse Customer Reaction Hypothesis behavioral framework. In the case of the deposit market the PT results correlate closer to the Bank's Collusive Hypothesis. Instead, in the UK and Canadian banking systems the data series produce quite symmetrical results, favoring the Adverse Customer Reaction Hypothesis behavioral approach, in both loan and deposit markets. In Japan, the asymmetry tests indicate that the loan market gives clearer results than the deposit market. In the loan market, the theoretical hypothesis of Bank's Collusive Hypothesis is favored. In the deposit market the Adverse Customer Reaction Hypothesis fits better when the CB rate is used as the PT policy variable, while the situation is reversed when the MM rate is used as the PT policy variable, i.e. the Bank Collusive Hypothesis behavioral approach is suggested.

Overall, we could figure out, that in UK and Canada all PT dynamics (in both asymmetry and rigidity aspects) seem to follow a quite similar pattern, while in US and Japan similarities only in the asymmetry aspects are indicated. In most cases, the element that was found to be in common was that the MM rates PT channel seems relatively more effective policy information vehicle than the CB rates one. The distinguishing and the accurate measurement of the different aspects of the PT interest rate process i.e. the instant PT effect, the speed and/or the time of the adjustment, the long run elasticity (degree of rigidity) and or the combination of these elements clearly enriches our understanding on the entire PT interest rate process. It becomes a useful practical guide in the monitoring of the monetary policy actions on country by country basis and at a coordinated (G5) level, as well.

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Appendix 1

Diagrams of the cumulative sum of positive and negative components of interest rates

Figure 1: UK

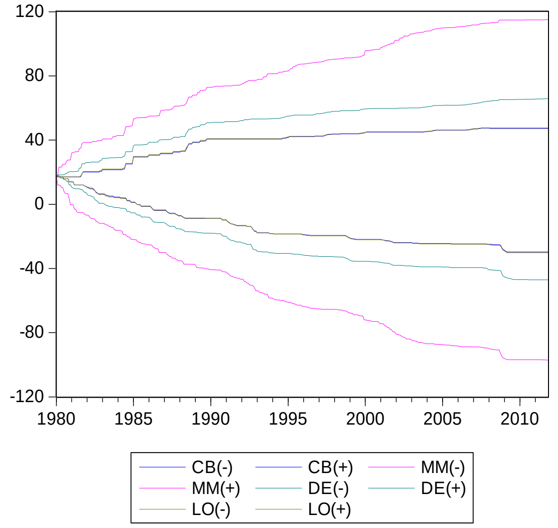

Figure 2: US

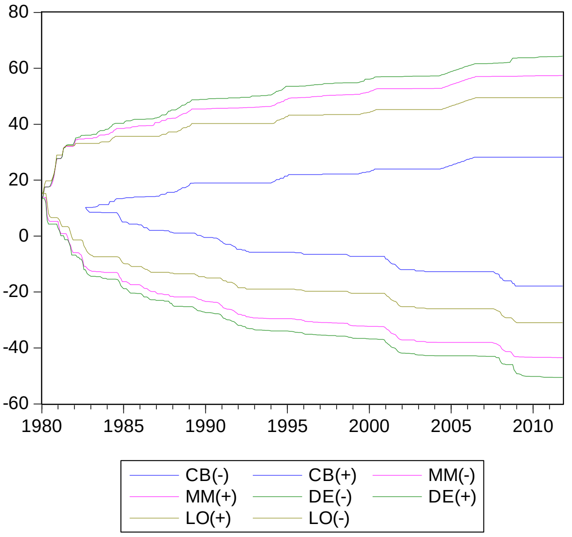

Figure 3: Japan

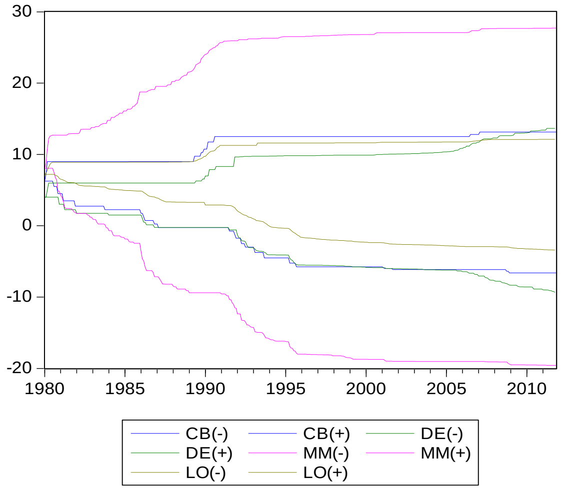

Figure 4: Eurozone

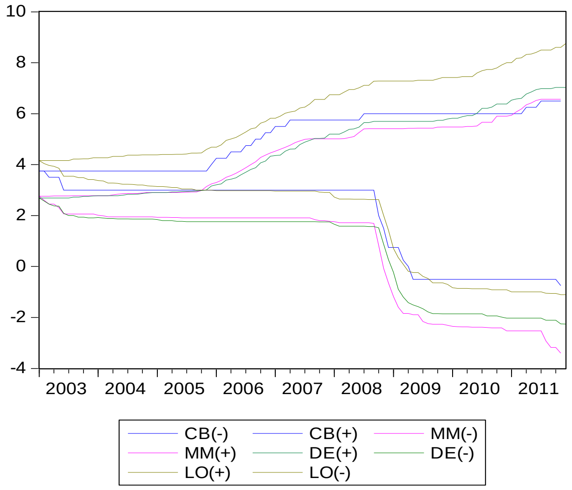

Figure 5: Canada

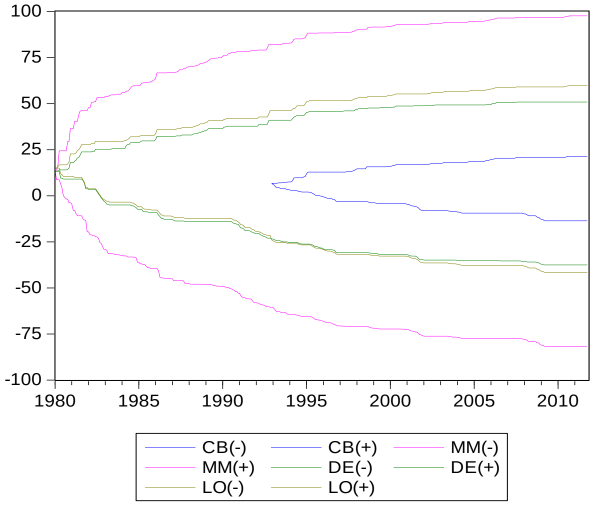

Table 1a: ADF unit root tests of wholesale rates [for I(1)]

Variables	US	Eurozone	UK	Canada	Japan
r_{CB}^{+}	-8.92 (2)	-3.67 (2)	-6.58 (6)	-10.62 (0)	-3.49 (12)
r_{CB}^{-}	-7.33 (1)	-2.85 (5)	-15.88 (0)	-7.02 (1)	-19.88 (0)
r_{MM}^{+}	-9.02 (9)	-5.49 (0)	-20.31 (0)	-9.08 (4)	-16.33 (2)
r_{MM}^{-}	-8.02 (5)	-4.23 (0)	-22.15 (0)	-11.79 (1)	-7.56 (2)

Note: In parenthesis, the order of the augmentation needed to eliminate any autocorrelation in the residuals of the ADF regression (*SIC criterion*) is presented.

Table 1b: ADF unit root tests of retail rates [for I(1)]

Variables	US	Eurozone	UK	Canada	Japan
r_{DE}^{+}	-5.96 (13)	-2.60 (2)	-11.95 (1)	-16.43 (0)	-16.35 (0)
r_{DE}^{-}	-3.99 (8)	-3.79 (0)	-16.28 (0)	-15.16 (0)	-16.33 (0)
r_{LO}^{+}	-6.35 (13)	-2.35 (3)	-18.11 (0)	-15.49 (0)	-10.98 (2)
r_{LO}^{-}	-9.77 (0)	-4.42 (0)	-11.57 (1)	-9.50 (1)	-7.41 (1)

Note: In parenthesis, the order of the augmentation needed to eliminate any autocorrelation in the residuals of the ADF regression (*SIC criterion*) is presented.

Table 2a: The US CECM pass-through estimates

Causality model	Positive Speed of Adjustment (θ^+)	Negative Speed of Adjustment (θ^-)	Positive Long run PT (φ^+)	Negative Long run PT (φ^-)	Immediate (Short run) Positive PT (δ_{wo}^+)	Immediate (Short run) Negative PT (δ_{wo}^-)	R^2
MM vs.CB	-0.81 (-6.09)†	-0.74 (-6.57)†	0.97	0.99	0.71 (8.3)	1.09 (17.2)	0.71
CB vs. MM	-0.78 (-9.08)	-0.76 (-9.12)	1.00	0.99	0.49 (9.9)	0.63 (17.2)	0.79
CB vs. De	-0.28 (-5.45)	-0.22 (-4.61)	1.02	0.92	0.59 (7.8)	0.58 (10.2)	0.62
MM vs. De	-0.39 (-6.46)	-0.32 (-5.88)	0.98	0.95	1.22 (21.0)	0.89 (22.8)	0.82
CB vs. Lo	-0.12 (-4.50)	-0.05 (-2.85)	0.97	0.92	0.34 (7.96)	0.33 (10.2)	0.78
MM vs. Lo	-0.10 (-3.88)	-0.05 (-2.64)	0.91	0.94	0.86 (21.4)	0.34 (9.90)	0.88

†. t - Statistics in parentheses. PT: Pass Through.

Table 2b: The US symmetric/asymmetric speed of adjustment results

Causality model	Symmetry Hypothesis $H_0 : \theta^+ = \theta^-$ Wald (χ^2) empirical values	Result
MM vs. CB	5.99	Positive asymmetry
CB vs. MM	2.37	Symmetry
CB vs. De	7.24	Positive asymmetry
MM vs. De	4.42	Symmetry
CB vs. Lo	11.21	Positive asymmetry
MM vs. Lo	7.84	Positive asymmetry

Note: We test the symmetry hypothesis by applying the Wald (χ^2) test. The critical value of χ^2 statistic with one degree of freedom is 3.84 (at 5% confidence level) and 5.02 (at 2.5% confidence level).

Table 2c: The US long run symmetric/asymmetric time adjustment results

Causality model	Positive Mean adjustment lag of a complete pass-through: $\gamma^+=(\varphi^+ - \delta_0^+)/\theta^+$	Negative Mean adjustment lag of a complete pass-through: $\gamma^-=(\varphi^- - \delta_0^-)/\theta^-$	Ψ-score Result ($\gamma^+ = \gamma^-$)
MM vs. CB	0.32	-	-
CB vs. MM	0.65	0.47	0.18
CB vs. De	1.53	1.54	-0.01
MM vs. De	-	0.18	-
CB vs. Lo	5.25	11.8	-6.55
MM vs. Lo	0.5	12	-11.50

Note: We accept *Symmetry* when $\psi \leq |2|$ (months) regarding the PT time completeness. When $|2| \leq \psi \leq |4|$ (months), we accept weak (negative or positive) asymmetry. When $\psi \geq |4|$ (months) we accept strong asymmetry.

Table 2d: The US long run PT rigidities

Causality model	Null Hypothesis $H_0 : \Phi^+ = 1$ Wald (χ^2) empirical values	Null Hypothesis $H_0 : \Phi^- = 1$ Wald (χ^2) empirical values	Result
MM vs. CB	6.23	1.10	Rejects the positive null
CB vs. MM	0.06	0.03	Both null are accepted
CB vs. De	0.80	4.75	Both null are accepted
MM vs. De	0.20	3.35	Both null are accepted
CB vs. Lo	0.41	1.52	Both null are accepted
MM vs. Lo	2.29	0.42	Both null are accepted

Note: We test the symmetry hypothesis by applying the Wald (χ^2) test. The critical value of χ^2 statistic with one degree of freedom is 3.84 (at 5% confidence level) and 5.02 (at 2.5% confidence level).

Table 2e: The US Total Symmetry (TS) Score

Causality model	Total symmetry score (TS)‡	Result
MM vs. CB	1.07	Total symmetry
CB vs. MM	1.03	Total symmetry
CB vs. De	1.41	Weak positive total asymmetry
MM vs. De	1.25	Weak positive total asymmetry
CB vs. Lo	2.52	Strong positive total asymmetry
MM vs. Lo	1.93	Strong positive total asymmetry

‡.Total symmetry (TS) = $\phi^+ * \theta^+ / \phi^- * \theta^-$.We accept total symmetry when $[0.80 - 1.0] \cong TS \cong [1.0 - 1.20]$. We accept weak total asymmetry when $[0.50 - 0.80] \cong TS \cong [1.20 - 1.50]$ and strong total asymmetry when $0.50 \leq TS \geq 1.50$.

Table 3a: The UK CECM pass-through estimates

Causality model	Positive Speed of Adjustment (θ^+)	Negative Speed of Adjustment (θ^-)	Positive Long run PT (φ^+)	Negative Long run PT (φ^-)	Immediate (Short run) Positive PT (δ_{wo}^+)	Immediate (Short run) Negative PT (δ_{wo}^-)	R^2
MM vs. CB	-0.33 (-4.83)	-0.35 (-4.94)	0.91	0.90	0.61 (14.7)	0.26 (6.4)	0.49
CB vs. MM	-0.84 (-9.10)	-0.85 (-9.14)	1.03	1.04	1.02 (12.9)	0.71 (7.2)	0.65
CB vs. De	-0.24 (-4.13)	-0.24 (-3.39)	0.94	0.95	0.95 (22.1)	0.95 (17.4)	0.74
MM vs. De	-0.20 (-3.13)	-0.19 (-3.11)	0.83	0.86	0.58 (11.0)	0.11 (2.2)	0.34
CB vs. Lo	-0.44 (-7.76)	-0.44 (-7.07)	1.01	1.01	1.01 (89.2)	0.98 (71.1)	0.97
MM vs. Lo	-0.36 (-5.25)	-0.38 (-5.36)	0.92	0.90	0.63 (14.9)	0.26 (6.50)	0.49

Table 3b: The UK symmetric/asymmetric speed of adjustment results

Causality Model	Symmetry Hypothesis $H_0 : \theta^+ = \theta^-$ Wald (χ^2) empirical values	Result
MM vs. CB	2.47	Symmetry
CB vs. MM	3.11	Symmetry
CB vs. De	0.02	Symmetry
MM vs. De	0.63	Symmetry
CB vs. Lo	0.005	Symmetry
MM vs. Lo	5.53	Negative asymmetry

Table 3c: The UK long run symmetric/asymmetric time adjustment results

Causality model	Positive Mean adjustment lag of a complete pass-through: $\gamma^+=(\varphi^+ - \delta_0^+)/\theta^+$	Negative Mean adjustment lag of a complete pass-through: $\gamma^-=(\varphi^- - \delta_0^-)/\theta^-$	Ψ-score Result ($\gamma^+ = \gamma^-$)
MM vs. CB	0.90	-1.82	-0.92
CB vs. MM	0.01	0.38	-0.37
CB vs. De	0.00	0.00	0.00
MM vs. De	1.25	3.94	-2.69
CB vs. Lo	0.00	0.06	-0.06
MM vs. Lo	0.80	1.68	-0.88

Table 3d: The UK long run PT rigidities

Causality model	Null Hypothesis $H_0 : \Phi^+ = 1$ Wald (χ^2) empirical values	Null Hypothesis $H_0 : \Phi^- = 1$ Wald (χ^2) empirical values	Result
MM vs.CB	11.18	8.82	Rejects both null
CB vs. MM	5.42	5.07	Rejects both null
CB vs. De	0.48	2.82	Accepts both null
MM vs. De	3.83	5.16	Rejects the negative null
CB vs. Lo	12.68	10.64	Both null are accepted
MM vs. Lo	7.19	12.27	Both null are accepted

Table 3e: The UK Total Symmetry (TS) Score

Causality model	Total symmetry score (TS)‡	Result
MM vs. CB	0.95	Total symmetry
CB vs. MM	0.97	Total symmetry
CB vs. De	0.98	Total symmetry
MM vs. De	1.01	Total symmetry
CB vs. Lo	1.00	Total symmetry
MM vs. Lo	0.96	Total symmetry

Table 4a: The Canada CECM pass-through estimates

Causality model	Positive Speed of Adjustment (θ^{+})	Negative Speed of Adjustment (θ^{-})	Positive Long run PT (φ^{+})	Negative Long run PT (φ^{-})	Immediate (Short run) Positive PT (δ_{wo}^{+})	Immediate (Short run) Negative PT (δ_{wo}^{-})	R^2
MM vs. CB	-0.83 (-6.53)	-0.84 (-5.08)	0.99	0.99	0.98 (21.6)	1.02 (22.5)	0.88
CB vs. MM	-0.89 (-7.56)	-1.01 (-7.61)	0.98	0.99	0.74 (20.6)	0.92 (22.4)	0.90
CB vs. De	-0.16 (-3.50)	-0.08 (-2.61)	0.69	0.79	0.47 (6.72)	0.55 (7.0)	0.53
MM vs. De	-0.27 (-6.65)	-0.20 (-5.14)	0.67	0.75	0.32 (8.4)	0.05ǂ (1.0)	0.35
CB vs. Lo	-0.45 (-4.01)	-0.31 (-2.97)	0.94	0.94	0.72 (12.2)	0.88 (14.3)	0.77
MM vs. Lo	-0.21 (-3.12)	-0.19 (-2.81)	0.80	0.84	0.46 (11.4)	0.11 (2.05)	0.51

ǂ. Statistically insignificant at 5%.

Table 4b: The Canada symmetric/asymmetric speed of adjustment results

Causality model	Symmetry Hypothesis $H_0 : \theta^{+} = \theta^{-}$ Wald (χ^2) empirical values	Result
MM vs. CB	0.33	Symmetry
CB vs. MM	2.12	Symmetry
CB vs. De	4.76	Symmetry
MM vs. De	12.93	Positive asymmetry
CB vs. Lo	2.66	Symmetry
MM vs. Lo	3.39	Symmetry

Table 4c: The Canada long run symmetric/asymmetric time adjustment results

Causality model	Positive Mean adjustment lag of a complete pass-through: $\gamma^{+}=(\varphi^{+}-\delta_0^{+})/\theta^{+}$	Negative Mean adjustment lag of a complete pass-through: $\gamma^{-}=(\varphi^{-}-\delta_0^{-})/\theta^{-}$	Ψ-score Result ($\gamma^{+}=\gamma^{-}$)
MM vs.CB	0.01	-	-
CB vs. MM	0.26	0.07	0.19
CB vs. De	1.38	3.00	-1.62
MM vs. De	1.29	3.50	-2.21
CB vs. Lo	0.48	0.19	-0.28
MM vs. Lo	1.61	3.84	-2.23

Table 4d: The Canada long run PT rigidities

Causality model	Null Hypothesis $H_0 : \Phi^{+} = 1$ Wald (χ^2) empirical values	Null Hypothesis $H_0 : \Phi^{-} = 1$ Wald (χ^2) empirical values	Result
MM vs. CB	0.13	0.21	Both null are accepted
CB vs. MM	0.02	3.11	Both null are accepted
CB vs. De	5.66	19.16	Both null are rejected
MM vs. De	16.47	35.89	Both null are rejected
CB vs. Lo	5.90	6.75	Both null are rejected
MM vs. Lo	3.08	4.70	Both null are accepted

Table 4e: The Canada Total Symmetry (TS) Score

Causality model	Total symmetry score (TS)ǂ	Result
MM vs.CB	0.98	Total symmetry
CB vs. MM	0.87	Total symmetry
CB vs. De	1.75	Strong positive total asymmetry
MM vs. De	1.20	Total symmetry
CB vs. Lo	1.45	Weak positive total asymmetry
MM vs. Lo	1.05	Total symmetry

Table 5a: The Japan CECM pass-through estimates

Causality model	Positive Speed of Adjustment (θ^+)	Negative Speed of Adjustment (θ^-)	Positive Long run PT (φ^+)	Negative Long run PT (φ^-)	Immediate (Short run) Positive PT (δ_{wo}^+)	Immediate (Short run) Negative PT (δ_{wo}^-)	R^2
MM vs.CB	-0.16 (-5.69)	-0.19 (-4.73)	0.73	0.70	0.10ǂ (1.3)	0.57 (12.0)	0.40
CB vs. MM	-0.16 (-5.90)	-0.21 (-6.10)	1.04	1.40	0.38 (3.6)	0.75 (11.6)	0.52
CB vs. De	-0.10 (-3.81)	-0.11 (-3.81)	0.89	0.77	0.04ǂ (0.6)	0.08 (1.92)	0.43
MM vs. De	-0.10 (-4.67)	-0.12 (-4.85)	0.70	0.61	0.19 (2.84)	0.15 (3.4)	0.34
CB vs. Lo	-0.12 (-4.36)	-0.03 (-5.00)	0.62	0.63	0.13 (4.70)	0.07 (4.7)	0.64
MM vs. Lo	-0.05 (-5.53)	-0.03 (-5.33)	0.47	0.67	0.003ǂ (0.11)	0.07 (4.46)	0.56

ǂ. Statistically insignificant at 5%.

Table 5b: The Japan symmetric/asymmetric speed of adjustment results

Causality Model	Symmetry Hypothesis $H_0 : \theta^+ = \theta^-$ Wald (χ^2) empirical values	Result
MM vs. CB	2.49	Symmetry
CB vs. MM	22.20	Negative asymmetry
CB vs. De	0.27	Symmetry
MM vs. De	6.89	Negative asymmetry
CB vs. Lo	11.67	Positive asymmetry
MM vs. Lo	11.61	Positive asymmetry

Table 5c: The Japan long run symmetric/asymmetric time adjustment results

Causality Model	Positive Mean adjustment lag of a complete pass-through: $\gamma^+=(\varphi^+ - \delta_0^+)/\theta^+$	Negative Mean adjustment lag of a complete pass-through: $\gamma^-=(\varphi^- - \delta_0^-)/\theta^-$	Ψ-score Result ($\gamma^+ = \gamma^-$)
MM vs.CB	3.93	0.68	2.94
CB vs. MM	4.12	3.09	1.02
CB vs. De	8.5	6.27	2.22
MM vs. De	5.1	3.83	1.26
CB vs. Lo	4.08	18.6	-14.5
MM vs. Lo	9.34	20	-10.66

Table 5d: The Japan long run PT rigidities

Causality model	Null Hypothesis $H_0 : \Phi^+ = 1$ Wald (χ^2) empirical values	Null Hypothesis $H_0 : \Phi^- = 1$ Wald (χ^2) empirical values	Result
MM vs.CB	27.9	166.4	Rejects both null
CB vs. MM	0.27	119.2	Rejects negative null
CB vs. De	1.20	25.8	Rejects negative null
MM vs. De	14.6	99.7	Rejects both null
CB vs. Lo	170.0	17.0	Rejects both null
MM vs. Lo	96.9	45.7	Rejects both null

Table 5e: The Japan Total Symmetry (TS) Score

Causality model	Total symmetry score (TS)ǂ	Result
MM vs.CB	0.87	Total symmetry
CB vs. MM	0.56	Weak negative total asymmetry
CB vs. De	1.05	Total symmetry
MM vs. De	0.95	Total symmetry
CB vs. Lo	4.11	Strong positive total asymmetry
MM vs. Lo	1.15	Total symmetry

Table 6a: The Eurozone CECM pass-through estimates

Causality model	Positive Speed of Adjustment (θ^{+})	Negative Speed of Adjustment (θ^{-})	Positive Long run PT (φ^{+})	Negative Long run PT (φ^{-})	Immediate (Short run) Positive PT (δ_{wo}^{+})	Immediate (Short run) Negative PT (δ_{wo}^{-})	R^2
MM vs. CB	-0.40 (-3.97)	-0.66 (-5.06)	1.01	0.89	0.10[‡] (0.40)	0.82 (7.3)	0.66
CB vs. MM	-0.32 (-3.81)	-0.37 (-3.52)	0.92	1.07	0.15[‡] (0.91)	0.58 (7.4)	0.74
CB vs. De	-0.27 (-4.58)	-0.81 (-4.25)	0.88	0.95	0.09[‡] (0.98)	0.19 (3.1)	0.89
MM vs. De	-0.11 (-1.96)	+0.10 (0.65)	1.39	0.82	0.29 (5.14)	0.50 (3.88)	0.91
CB vs. Lo	-0.19 (-3.93)	-0.42 (-5.55)	0.86	0.95	0.08[‡] (0.66)	0.20 (3.3)	0.73
MM vs. Lo	-0.21 (-2.75)	-0.20 (-2.24)	1.11	0.83	0.44 (2.4)	0.18 (2.4)	0.78

Table 6b: The Eurozone symmetric/asymmetric speed of adjustment results

Causality Model	Symmetry Hypothesis $H_0 : \theta^{+} = \theta^{-}$ Wald (χ^2) empirical values	Result
MM vs. CB	4.93	Symmetry
CB vs. MM	0.33	Symmetry
CB vs. De	14.10	Negative asymmetry
MM vs. De	-	-
CB vs. Lo	15.50	Negative asymmetry
MM vs. Lo	0.01	Symmetry

Table 6c: The Eurozone long run symmetric/asymmetric time adjustment results

Causality Model	Positive Mean adjustment lag of a complete pass-through: $\gamma^{+}=(\varphi^{+}-\delta_0^{+})/\theta^{+}$	Negative Mean adjustment lag of a complete pass-through: $\gamma^{-}=(\varphi^{-}-\delta_0^{-})/\theta^{-}$	Ψ-score Result ($\gamma^{+}=\gamma^{-}$)
MM vs. CB	2.27	0.10	2.17
CB vs. MM	2.40	1.32	1.08
CB vs. De	0.97	2.81	1.84
MM vs. De	10.0	-	-
CB vs. Lo	4.10	1.78	2.32
MM vs. Lo	3.19	3.25	-0.06

Table 6d: The Eurozone long run PT rigidities

Causality model	Null Hypothesis $H_0 : \Phi^{+} = 1$ Wald (χ^2) empirical values	Null Hypothesis $H_0 : \Phi^{-} = 1$ Wald (χ^2) empirical values	Result
MM vs. CB	28.6	0.14	Rejects the negative null
CB vs. MM	4.66	2.08	Both null are accepted
CB vs. De	13.5	4.89	Rejects the negative null
MM vs. De	-	4.70	Both null are accepted
CB vs. Lo	2.43	2.19	Both null are accepted
MM vs. Lo	12.47	1.88	Rejects the negative null

Table 6e: The Eurozone Total Symmetry (TS) Score

Causality model	Total symmetry score (TS)[‡]	Result
MM vs. CB	0.68	Weak negative total asymmetry
CB vs. MM	0.74	Weak negative total asymmetry
CB vs. De	0.30	Strong negative total asymmetry
MM vs. De	-	-
CB vs. Lo	0.40	Strong negative total asymmetry
MM vs. Lo	1.40	Weak positive total asymmetry

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