Long-run Price Behavior in the Gasoline Market- The Role of Exogeneity

Seyedeh Asieh H. Tabaghdehi[a] and John Hunter[b]

[a] *Department of Accounting, Finance & Economics, Regents University London, Inner Circle, Regents Park, London NW1 4NS, United Kingdom of Great Britain and Northern Ireland*

[b] *Department of Economics and Finance, Brunel University, Uxbridge, Middlesex UB8 3PH, England, United Kingdom of Great Britain and Northern Ireland*

Abstract

Concentrating on cointegration analysis, this study aims to detect key features of long-run price behaviour in the US gasoline market. This research by following Forni (2004) first examines the stationarity and cointegration properties of the weekly gasoline prices across eight different regions of the US. Second it considers the arbitrage and the extent to which the market prices respond to each other in terms of both cointegrating and weak exogeneity in the long run. Results reveal the importance of the long-run information in a competitive market. Also, the gasoline market in US is not effectively functioning and this suggests to a change in the regulation of the gasoline market to enhance competition. Significant implication for consumers and policy makers are emphasized.

Key Words: Cointegration, Cointegrating Exogeneity, Competition, Equilibrium Price Adjustment, Stochastic Trend, Weak Exogeneity

1. Introduction

Gasoline is one of the products with the highest price variation in the world and recent dramatic changes in gasoline prices significantly affect the consumer and business behavior (Al-sasi et al., 2017). The gasoline price is significantly influenced by innovation, technological progress (Ramberg et al., 2017), and political instability in the global economy. The key process in the production of gasoline takes the product from the oil field to the gas station pump in four steps: exploration, refining, distributing the refined oils to the different companies and regions, selling the product (Wrights, 2017). The price of the gasoline at the pump includes a considerable amount of tax, which is a vital revenue stream for the government (Coglianese et al., 2017). The gasoline market has generally been considered as a competitive market (Alm et al., 2009) because of the following reasons: the product is homogeneous (Nishida & Remer, 2018), there are strict rules as to what can be added to fuel, consumers are less influenced by branding, there are many suppliers and consumers, and a significant amount of price related information is commonly available. Nevertheless, pump prices at the gas station do differ in terms of location, local tax levels and services provided by the outlet.

This research explore how could the long-run price differentiation continue in the gasoline market. In the short-run there is likely to be some price differentiation related to regional factors, but it seems less easy for this to arise in the long run. Observing the process that gives rise to the equilibrium in a market can confirm the appropriateness of the structure and the competitiveness of the market. This is very important since the pricing anomalies in the long run between regions would affect regional activity and consumers might react radically towards high price differentials (Garner, 1981) by moving job and/or house to reduce travel costs, by the purchase of more fuel-efficient vehicles etc. However, a persistent price differential suggests discrimination and identifies the possibility of market power and informational inefficiency (Fafaliou & Polemis, 2011). The result of this study contributes profoundly to the consumers' decision making (Garner, 1981; Parinandi & Hitt, 2018) and the long-run management strategy of this crucial sector.

The information on price can be provided efficiently to customers and that consumers can monitor retail gasoline prices is one of the main concerns for the global economy. As Ogbuabor et al. (2018) state constant monitoring and efficient consumer welfare policies can lead the economy to enhance competition and social welfare. However, government intervention in market regulation may be required to control price discrepancies and improve market structure (Chen et al., 2018). The research philosophy here is for the price of any homogeneous good in an identical market a cointegrating relation developed by Johansen (1995) is required, as arbitrage should remove mispricing in the long run (Cerqueti et al., 2018). This article discusses further the development of weak exogeneity to investigate the in implication of cointegration for policy analysis as this has been reviewed in early literature (Hendry & Juselius, 2001; Hunter & Tabaghdehi, 2013; Kurita, 2018; Moral-Benito & Seven, 2015; Trapani, 2015). Furthermore, Chandra &

Tappata (2008) pointed out consumer search is a significant and important factor affecting price dispersion in the gasoline market. This study investigate that could the price dispersion arises from the imperfect consumer information (Van Hoomissen, 1988).

By contributing to the growing research on competitive price behaviour and the role of exogeneity in this matter (Cerqueti et al., 2018), this study explores whether gasoline prices in US follow each other in the long run and detect any anomalies in relevant market. How the number of long-run relations can be determined simultaneously to explain the US gasoline market structure? Moreover, it draws on the theories of long run price leadership to investigate further the role of common trend and exogeneity in illumination of the competitive structure of the gasoline market.

Prior researches emphasize that via using the cointegration and error correction model (ECM) the gasoline market is not coherent globally and the degree of competition is different between countries or within one country, and this generates price volatility and gasoline price asymmetry (Angelopoulou & Gibson, 2010; Fafaliou & Polemis, 2011; Fotis & Polemis, 2013; Galeotti et al., 2003; Polemis, 2012). Hence, in US gasoline market the specific pattern of regional price differentiation may be constantly affecting the market efficiency. To examine this, we focus on whether the competitive behaviour in gasoline market can be verified from the long-run decomposition of prices, and whether the conditional Error Correction Model (ECM) and VAR approach for testing cointegration can be used to develop the long-run relationships and consider the potential for arbitrage correction in a competitive market. This research hypothesis relates to the possibility that a sequence of prices that deviate from equilibrium give rise to an arbitrage opportunity that is correcting in the long run. The arbitrage opportunity arises when there are *N-1* arbitrage correction terms across *N* markets and this is consistent with a broad market definition and relates to Long-run Equilibrium Price Targeting (LEPT) (Burke & Hunter, 2007; Burke & Hunter, 2011; Hunter et al., 2017). While, a narrow market involves less than *(N-1)* cointegrating relations, supporting that some prices do not respond to the other prices in the market. This may occur when the long-run causality related to cointegrating exogeneity is observed, or detect that one or more price series is weakly exogenous (WE) for all the cointegrating vectors and the extent to which one or more region may be important in relation to setting price (Hendry & Juselius, 2001;

Hunter & Tabaghdehi, 2013; Kurita, 2018). In section 2 we review the background of the research on price dispersion and law of one price, long-run equilibrium price targeting, arbitrage and efficient market hypothesis followed by essential literature on stationarity, error correction, and exogeneity. Section 3 identifies the data for the empirical analysis. In section 4 we test for weak exogeneity, long-run exclusion, and strict exogeneity to investigate the nature of parallel pricing in the gasoline market in the long run. Finally, in Section 5 we offer our conclusions.

2. Background of the research

2.1 Price dispersion and the law of one price

It would be natural to assume that competitive behaviour ought to be reflected in price movement. La Cour & Mollgaard (2002) focused on the appropriateness of a legal definition that might be used to define anti-trust behaviour. Their focus was on the extent to which a firm may be able to operate independently of its competitors. While Forni (2004) has approached the problem from a slightly different manner in terms of categorizing a market as broad or narrow and thus defining the extent of a market. Where the breadth of a market within a region is linked to the degree of price responsiveness across a physical entity or the degree to which there is interaction in firms' prices. If prices are sticky, then it should be possible without the limitations of law or physical borders within a market to arbitrage the product and this links to the related concept of the law of one price (Forni, 2004, Hunter & Tabaghdehi, 2013). In particular, the mechanism by which firms react to pricing decisions has been considered by early literature such as Markham (1952) or Stigler (1947), where they provide a rationale for price stickiness. More recently attention has been paid to breaking down the nature of these price responses both theoretically and empirically (Hunter & Tabaghdehi, 2013; Hunter et al., 2017; Kurita, 2018). From a theoretical perspective, Buccirossi (2006) considers whether competitive behaviour requires firms to adopt parallel pricing. This corresponds to what has been called the law of one price that implies that in any market the price of the identical goods in terms of quality and specification must tend to be the same for the market to be efficient regardless of where they are traded. The law of one price can be reformulated in the case of transport and transaction cost (Cardebat et al., 2017). When prices at different locations differ as a result of transport and transaction cost, arbitrage will give rise to price correction and when the market is efficient it might be anticipated that such adjustment should be fast. The Error Correction Model (ECM) would appear to be an appropriate mechanism for analyzing the law of one price in the long-run (Johansen, 1995). However, in later study Asplund & Friberg (2001) indicated that the law of one price does not hold for identical goods even when they are sold in the same location. Yet, Goldberg & Verboven (2005) specified that there is a convergence towards the absolute and the relative version of the Law of One Price, and suggest that institutional changes can diminish the main source of segmentation in international markets.

2.2 Long-run Equilibrium Price Targeting (LEPT) and consumer harm

Much of the earlier empirical literature applied to time series data is well summarized in a report for the United Kingdom Office of Fair Trading (OFT) by LECg (1999) where the focus was on price correlation and causality. They suggest that correlation was an indication of collusion (Maunder, 1972). Further consideration was made of endogeneity by Slade (1986) again an indication that certain firms pricing decisions were driving the market. More recently, the distinction has been made between the long run and the short- run. One reason might be that it may be easier to encourage a committee or jury that irregularity in pricing in the long-run is serious enough to lead to legal action as harm to the consumer (Hunter & Tabaghdehi, 2014; Hunter et al. 2017). Consumer satisfaction is an important factor in every economy (Garner, 1981) and consumer harm has been defined in terms of consumer detriment (Hunter et al., 2001). Detriment can be measured either directly or indirectly, the direct detriment (Garner, 1981) measures relate to the extent of legal activity and complaint in terms of the delivery and quality of the product delivered. However, monitoring whether the consumer is damaged by corporate inactivity is not straightforward. Whereas the indirect detriment measures trend and stationary components and via cointegration it is possible to see that the price that is weakly exogenous is not reacting to the other prices in the long run. A further problem arises when there are insufficient trends which this occurs with the finding of what has been termed by Hunter (1990 and 1992) as cointegrating exogeneity (CE). This is less clear when parallel pricing is observed as CE this leads to a subset of prices that interact differently from the other price series. So it is easier to make this distinction in the light of the finding of Long-run Equilibrium Price Targeting (LEPT) introduced by Burke & Hunter (2011) where the price response can be seen to have broken down for more than one of the price series. Otherwise there may be more than one stochastic trend and this may be linked to some form of market segmentation and the natural finding that the price responses are blocked in some way. This blocking may by quasi-diagonal (Hunter, 1992) or even give rise to the finding that a price is weakly exogenous for a sub-block of long-run price relations. In these cases, the segmentation may identify where the market failure has arisen (Hunter & Tabaghdehi, 2013; Hunter et al., 2017).

The analysis of Forni (2004) and some commercial studies (Milosevic et al., 2018) was limited by the extent of the data, but with a more extensive data set, then the tests are likely to perform better in the confines of a system (Kurita, 2018) and be better sized in the presence of volatility. Analysing pricing properties may be effective in testing for market definition when the persistence in volatility is reduced by consideration of the price proportions. However, when volatility is quite persistent then in a system where the largest eigen value (spectral radius) of the ARCH polynomial exceeds 85% as is suggested by Rahbek et al. (2002), the Johansen test statistic does not converge at a rate anticipated in the literature to the conventional asymptotic distribution. Rahbek et al. (2002) find using different simulation experiments with different mean and variance equations that asymptotic convergence may only occur in samples that exceed 600 and for some of their simulations even 1000 observations.

2.3 Arbitrage and the Efficient Markets Hypothesis (EMH)

The price differentiation in different regions of one country identifies that prices are not fully reflecting all available information at any point in time, which this brings economist concerns over market efficiency. The market efficiency hypothesis was first developed by Fama (1970) specifies that at any specific time prices should fully reflect all available information on the market. This implies any information spreads rapidly throughout all participants. Since all participants have identical information, there is an invisible agreement, which causes unremitting price differentiation without facing an arbitrage opportunity. According to Fama (1979) there are three types of market efficiency as; weak form efficiency, semi-strong form efficiency, and strong form efficiency. The difference between these three forms of market efficiency (Fama, 1991; Kristoufek, 2018) is based on the nature of the available information. In weak form efficiency the available information is historical prices and future prices can be predicted from historical prices signifying no chance of profit creation. Semi-strong form of efficiency reflects all public information in price movements, and finally strong form efficiency indicates that all types of information is reflected in the price movements which signifies no opportunity of profit making from that information (Fama, 1991). In financial markets it is suggested by Fama (1998) that specific patterns of pricing behaviour in the market can give rise to profitable opportunities from arbitrage. This arbitrage opportunity cannot survive for long and over time they will dissipate as others seek them out.

In energy market the energy storability makes it suitable for price arbitrage and hedging. An arbitrage opportunity in the gasoline market will increase energy transfer from the high-price regions to the low-price regions where the market size changes in both regions respectively. Therefore, arbitrage opportunities should direct the market price towards a stable equilibrium price. In the short-run, arbitrage decreases the production efficiency in high-price regions since the production level increases, but in long run it moderates the regional price discrepancy and all this informs the positive welfare effect of arbitrage in the economy as a result of "allocative efficiency" (Brueckner, 1982; Rious & Rossetto, 2018). However, increases in the production level for the high-price region, indicates a decrease in "productive efficiency". Therefore, there could be a negative impact from the arbitrage opportunity to welfare. If the long-run locational price dissimilarities continue in one country as a result it could damage the society as it gives rise to the greatest profit for the monopolist. Hence, to increase the welfare it is required a competitive process to reduce the search and switching cost by subsidizing information for consumers. However, in a country the size of the US, the arbitrage opportunity may be limited by the extent to which there might be regional or physical barriers. Hence, to further investigate the perfect completion in US gasoline market we apply Johansen cointegration test as an effective empirical method to study an efficient market definition and the nature of the integration and cointegration of the gasoline price series. In the following section, data and the methods for testing the hypothesis are outlined.

3 Data and Methodology

3.1 Data collection

In this study we consider the time series properties of weekly gasoline prices across eight different regions in the US (West Coast (WC), Central Atlantic (CA), East Coast (EC), Gulf Coast (GC), Lower Atlantic (LA), Midwest (MW), New England (NE), Rocky Mountains (RM)) from May 1993 to May 2010. Considering regional gasoline infrastructure across the US we test cointegration on (log) first differences of gasoline prices in eight different regions. In this study we consider the time series properties of weekly gasoline prices across eight different regions in the US (West Coast (WC), Central Atlantic (CA), East Coast (EC), Gulf Coast (GC), Lower Atlantic (LA), Midwest (MW), New England (NE), Rocky Mountains (RM)) from May 1993 to May 2010. Considering regional gasoline infrastructure across the US we test cointegration on (log) first differences of gasoline prices in eight different regions.

3.2 Exogeneity and causality analysis- Test of weak exogeneity and parallel pricing

Using the Johansen trace test (1991) on eight regional gasoline prices (r=8) in US, we identified that there are 5 cointegrating vectors (r = 5) for a test applied at the 5% level (See Table 1). This implies that there are 3 stochastic trends (N-r = 3) and this does not correspond with the results of cointegration test based on the single equation methods. If the cointegrating rank (r) is less than N-1 then there are more stochastic trends than might be anticipated by a single competitive market which this implies that Long-run Equilibrium Price Targeting (LEPT) cannot hold and the market is segregated (Hunter & Tabaghdehi, 2013). Therefore, further analysis is required to interrogate the nature of the inter-relations that may impact price behaviour. Here, each long-run relation will be forced by up to three trends so there may be up to three different prices driving the system in the long run. There may also be the type of separation in the market place related to cointegrating exogeneity and quasi-diagonality (Hunter, 1992) or weak exogeneity (Johansen, 1992). In the first instance gas prices in different parts of the US may respond to a different stochastic trend, or in some parts of the US there may be relations linked to all trends and in other to a subset of trends. Considering N-r = 3 identifies that up to three variables may be weak exogenous implying that they are not affected by the long-run price behaviour in the other segments of the market. Such segmentation may be consistent with price differentiation and these anomalies are indicative of collusive agreements or when long-run causality can be detected then there is potential for leadership by some of the major gasoline suppliers.

Table 1 goes here

Granger (1969) devised a means to test for causality in the context of stationary series, while the concept of cointegrating exogeneity was developed by Hunter (1990) to handle causality between non-stationary variables in the long- run. Giannini & Mosconi (1992) tested Granger Causality subject to cointegrating exogeneity. Testing for causality found useful (Gordon, Hobbs & Kerr, 1993; Horowitz, 1981; Ravallion, 1986; Slade, 1986) in defining market boundaries. However here, subject to the finding on rank, the focus will be on exogeneity restrictions and long-run exclusion. Here by following Hendry & Juselius (2001) we consider the conventional VECM, but with eight potentially inter-related market prices and r = N-3 long-run relation. Also following De Vany & Walls (1999) we consider cointegration as a system and that may relate to the more general case of Long-run Equilibrium Price Targeting (Burke & Hunter, 2011). Cointegration across the system gives rise to a set of long-run relations that are tested jointly. Furthermore, the finding of weak exogeneity can distinguish between parallel pricing and aggressive price leadership (Hunter & Burke, 2007; Hunter et al., 2017; Kurita, 2008; Kurita, 2018). Hence, we examine US gasoline market through weak exogeneity, long-run exclusion and strict exogeneity hypothesis.

Irrespective of *r*, when the series are cointegrated there is a restricted long-run parameter matrix: $$\mathbf{\Pi}=\boldsymbol{\alpha}\boldsymbol{\beta}'$$

These can be identified in turn by setting $\boldsymbol{\alpha}'=[\mathbf{A}\ \ \mathbf{I}_r]$ or $\boldsymbol{\beta}'=[\mathbf{I}_r\ \ \mathbf{B}]$ and then we either find the $\boldsymbol{\beta}$ specifying the long-run relations, or we identify all the elements of $\boldsymbol{\alpha}$ that gives rise to adjustment to each cointegrating relation in the short-run. Let the i^{th} column vector of $\boldsymbol{\beta}$ be denoted as $\boldsymbol{\beta}_{.i}$ subject to a normalisation on the i^{th} element, then $\boldsymbol{\beta}_{.i}=[\beta_{1i} \quad \ldots \quad 1 \quad \ldots \quad \beta_{Ni}]'$. The existence of cointegration in a VAR system implies that the stochastic trends are combined as r stationary linear combinations; there are N-r of these trends and no more than N-r weakly exogenous variables (Johansen, 1995). Here, there are eight price series and the corresponding unrestricted model is specified as follows:

$$\Gamma(L)\ \Delta p_t = \alpha\ \beta' p_{t-1} + \varepsilon_t$$

$$\Delta p_t = \begin{bmatrix} \Delta p_{1t} \\ \vdots \\ \Delta p_{Nt} \end{bmatrix},\ \varepsilon_t = \begin{bmatrix} \varepsilon_{1t} \\ \vdots \\ \varepsilon_{Nt} \end{bmatrix}$$

$\Gamma(L) = \begin{bmatrix} I & -\Gamma_1 & \dots & -\Gamma_{p-1} \end{bmatrix}$ and Γ_i an N×N matrix of dynamic parameters. Hence for examining the gasoline market structure and identifying the number of long-run relations, it is necessary to impose further restrictions on the VAR model. Following Burke & Hunter (2011), Hunter & Simpson (1995), Hunter et al. (2017) and Johansen (1992) weak exogeneity in the long-run has been identified by imposing a restriction on each row $\boldsymbol{\alpha}_{i.}=[0 \quad 0 \quad 0 \quad 0 \quad 0]$ from $\boldsymbol{\alpha}$ in turn for i= 1, … , 8 and that excludes the long-run from each equation in the system. While long-run exclusion (Juselius, 1995) can be tested by imposing restrictions in $\boldsymbol{\beta}_{i.}=[0 \quad 0 \quad 0 \quad 0 \quad 0]$ from $\boldsymbol{\beta}$ in turn for i=1, …, 8 that excludes variable from all the cointegrating vectors. Therefore weak exogeneity and long-run exclusion impose $\boldsymbol{r}$ restrictions on $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ for the variable excluded. Strict exogeneity combines the weak exogeneity and long run exclusion restrictions for the i^{th} variable and imposes $2\boldsymbol{r}$ restrictions for each variable excluded from $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$. The restrictions are tested by further likelihood ratio test statistics, which are conditional on $\boldsymbol{r}$. A further component of the process used to identify is to select the most appropriate normalisation of the data by imposing the restriction below:

$$\beta_{ii}=1, \text{ for } i=1, \dots, 5$$

$$\beta_{ij}=0\ , \text{ for } \begin{cases} i = 1, \dots, 5 \\ j = 1, \dots, 5\ . \\ i \neq j \end{cases}$$

Bauwens & Hunter (2000) suggest it is important not to normalise on a variable that is weakly exogenous. Furthermore Boswijk (1996) suggests the same in the case of a variable that is not long-run excluded. Also for parallel pricing let each column of $\boldsymbol{\beta}$ as $\boldsymbol{\beta}_{.i}$

= [0 … $\boldsymbol{\beta}_{ii}$ … $\boldsymbol{\beta}_{Ni}$]′ to be further restricted so that $\boldsymbol{\beta}_{ii}$ = 1 and $\boldsymbol{\beta}_{Ni}$ = -1 to confirm a long-run correspondence between the price series.

4. Results and analysis

To examine the long-run relationship of the gasoline prices in the US market and explain their implication on consumers' behavior, weak exogeneity, long-run exclusion and strict exogeneity is verified and discussed. In Table 2, tests of cointegration are derived from the VAR model and the results related to the imposed restrictions on $\boldsymbol{\alpha}$ or $\boldsymbol{\beta}$ or both to test weak exogeneity, long-run exclusion and strict exogeneity are presented accordingly. There are 21 lags in the VAR estimations.

The first block of results in Table 2 relate to a weak exogeneity test conditional on $\boldsymbol{r}$ = 5 and from the p-values it can be determined that the log price of the Gulf Coast, the Lower Atlantic and the Mid-West are potentially weak exogenous for $\boldsymbol{\beta}$. Therefore, all N-r = 3 variables are weak exogenous for $\boldsymbol{\beta}$ giving rise to 5 other restrictions are clearly rejected at the 5% level. Hence there are good reasons to order the system based on these tests as when the system is normalized. This can be seen as being related to conditioning on the series most likely to be exogenous (Hunter & Simpson, 1995). Whereas here, the result of the WE test suggests considerable weak exogeneity in the Gulf Coast and Lower Atlantic gasoline prices and more significantly Gulf Coast price changes will effect directly to the other region's prices.

Table 2 goes here

Prior to further investigation of $\boldsymbol{\alpha}$, following Juselius (1995) the next section of Table 2 presents tests of long-run exclusion. These test results are significant for all regions indicating the appropriateness of the rank condition and the likely robustness of the propositions on the cointegrating vectors. When there are long-run excluded (LE) variables, then it would be appropriate to order the system using this test prior to normalization, because it is not appropriate to normalise on a variable that may be the LE and this can be viewed as one of the criteria devised by Boswijk (1996) to identify the long-run. In terms of the indication of anti-competitive behavior, finding a variable that is not long-run excluded (LE) indicates that it may interact with all the other variables in the long-run, as that variable must be present in at least one cointegrating vector. The final section in Table 2 relates to strict exogeneity and that combines the weak exogeneity with the long-run exclusion restriction. However, this will not be considered further as none of the price series appear to be strictly exogenous. The last variable in the revised system is the GC price and **α** is restricted to impose the weak exogeneity and this price will condition the long run. Then based on subsequent investigation a further 21 restrictions are imposed on **α** and then **β**, and this gives rise to the matrices based on restricted coefficients:

$$\alpha = \begin{bmatrix} -0.252 & 0.222 & 0.0 & -0.03 & 0.025 \\ -0.189 & 0.223 & 0.0 & -0.018 & 0.021 \\ 0.0 & -0.182 & 0.025 & -0.198 & 0.077 \\ -0.109 & 0.0 & 0.0 & -0.045 & 0.028 \\ -0.187 & 0.314 & 0.0 & 0.0 & 0.014 \\ 0.0 & 0.0 & 0.038 & 0.0 & 0.0 \\ 0.0 & 0.0 & -0.014 & 0.0 & -0.053 \\ 0.0 & 0.0 & 0.0 & 0.0 & 0.0 \end{bmatrix} \text{ and}$$

$$\beta' = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & -0.371 & -0.638 \\ 0 & 1 & 0 & 0 & 0 & 0 & -0.429 & -0.611 \\ 0 & 0 & 1 & 0 & 0 & -0.933 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & -2.707 & 0.66 & 1.134 \\ 0 & 0 & 0 & 0 & 1 & 0 & -0.39 & -0.671 \end{bmatrix} = \begin{bmatrix} \beta'_{.1} \\ \vdots \\ \beta'_{.5} \end{bmatrix}$$

The system is ordered such as $p'_t = [p_{CA_t} \quad p_{EC_t} \quad p_{RM_t} \quad p_{NE_t} \quad p_{LA_t} \quad p_{WC_t} \quad p_{MW_t} \quad p_{GC_t}]$. These restrictions give rise to the further test of a likelihood ratio test of 20.936 and from the p-value = [.7453] which it is not possible to reject them. In addition, the likelihood ratio test statistic related to further 21 over-identifying restrictions is computed as 15.8106 and since the relevant p-value is [0.7802] therefore these are also not significant. Following the imposition of the normalization rule the first ***r*** columns of **Π** reflect α and as a result of this it can be observed that on top of the WE restriction there is a block triangular section that is zero and this is consistent with the Mid-West and the West-Coast prices being cointegrating exogenous for $\beta_{.1}$ and $\beta_{.2}$ (the first two cointegrating vectors). More strictly a row from α annihilates a column from β or $\mathbf{\Pi}_{ij}=\alpha_{.i}\,\beta_{j.}=0$ (Hunter & Simpson, 1995) or more generally the necessary condition for cointegrating exogeneity is $\mathbf{\Pi}_{21}=0$, an $N_2\times N_1$ sub-block of **Π** (Hunter, 1990).

The former is consistent with the joint test of WE that implies the prices for the Mid-West and the Gulf Coast might be considered WE for β. This would indicate a system that could be conditioned on both prices implying two stochastic trends relating to the GC and the MW price. However, it was decided from inspection of α that as the MW price seemed to depend on $\beta_{.3}$ and $\beta_{.5}$ and it was better to consider as a cointegrating exogenous for these two vectors. This seems pertinent as the MW price has a very similar coefficient in $\beta_{.1}$, $\beta_{.2}$ and $\beta_{.5}$. The long-run non-causality related with cointegrating exogeneity, seems to extend to $\beta_{.4}$. Similarly the block triangularity of $\mathbf{\Pi}$ implicit in the structure of the restricted α and β indicating that the West-Coast price is cointegrating exogenous for $\beta_{.1}$ and $\beta_{.2}$. However, in this case this is trivial as the terms related to the West-Coast prices are excluded from these equations, but it can be observed from α that $\beta_{.2}$, is the only vector that appears in the dynamic equation for the WC price and showing that it is also cointegrating exogenous for $\beta_{.4}$. Considering the cointegrating vectors in turn, it follows from the restriction on $\beta_{.1}$ and $\beta_{.2}$ that the Central Atlantic and East-Coast prices are driven by the same cointegrating exogenous and weak exogenous variables of Gulf Coast and Mid-West prices. These prices for all intents and purposes have similar coefficients and the two prices would appear to define a sub-block variant of Long-run Equilibrium Price Targeting (LEPT) proposed by Burke & Hunter (2011) that relates to $\beta_{.1}$ $\beta_{.2}$ and $\beta_{.5}$. Here we will focus on the equations explaining the prices for the Central Atlantic and the East-Coast that are being forced and as a result the Gulf Coast and Mid-West prices do not reflect the prices related to these regions.

The form of $\beta_{.3}$ appears very close to what has been termed as parallel pricing. It should be recalled this only relates to LEPT when there are *N-1* parallel vectors. Here this defines a partitioned market so the Rocky Mountain and West-Coast prices are reflected in each other and none of the other prices are forcing this long-run relation specifying that they share a common stochastic trend. The cointegrating vector $\beta_{.4}$ relates to the New England price and this is driven by the Gulf Coast, Mid-West and West Coast prices. This appears to indicate that the New England price reflects information from across the US. This is given further support as the dynamic equation from the VAR is also impacted by the correction related to $\beta_{.1}$ that explains the Central Atlantic price in the long-run and

$\beta_{.5}$ that explains the Lower Atlantic price in the long-run. Based on the normalisation this may be viewed as the own vector, but the form of $\beta_{.4}$ seems less easy to understand given that it is anticipated that we observe parallel pricing and LEPT. However, this vector can be seen as a combination of three parity relations between the New England and West Coast price, the West Coast and Mid-West price, and the West Coast and Gulf Coast price. Furthermore, the NE prices are not being reflected in prices for the GC, MW and WC.

Moreover the long-run equation explained by $\beta_{.5}$ relates the Lower Atlantic to the Mid-West and the Gulf Coast prices. The GC price is again the driver and is not impacted by the LA price in the long-run. This is consistent with the investigation of the trivariate system results in Burke & Hunter (2012) and Kurita (2008). Finally the result suggest that, as the MW price is dependent on $\beta_{.1}$ and $\beta_{.5}$, then it is appropriate to say that a linear relation between the Lower Atlantic and Mid-West price is forced by the Gulf Coast price and so in this case the MW and the LA are interdependent. This implies there is a common shock as all series depend on one common driver. More, Johansen et al. (2000) argues that the cointegration test might be invariant to shocks when the shocks are common and one of the series is exogenous. Hence, the exogenous variable appears to force the long-run equations and for the weakly exogenous variable this is essentially a random walk. In the latter case the Gulf Coast price is only impacted by shocks that effect this segment of the market and this is contrary to a competitive market. Thus contrary to a competitive market, it is partitioned in the long-run. To this end from empirical result the regional gasoline pricing may not be consistent with a fully functioning gasoline market in the US. There may be geographical or structural reasons for this to occur. However, Shin et al (2011) considers a single equation so the long-run analysis will in one dimension be sensitive to the non-linearity, but in the other hand they have not paid attention to the extent to which the market is spanned (Kurita 2018). Hence, the finding on the long-run relationship should be unique and consistent with the linear hypothesis. Non-linearity should arise when this is not the case as then the long-run relationship is not to be found (Burk & Hunter, 2011; Hunter & Tabaghdehi, 2014; Hunter et al., 2017; Kurita, 2018).

5. Discussion and implication

For non-stationary variables, the Johansen methodology of cointegration and exogeneity testing appears an appropriate approach to investigate market performance (Herzer & Donaubauer, 2018; Hunter et al., 2017). These empirical findings indicate that gasoline prices for different regions in the US are cointegrated and this suggests that the market may not be distinct. Forni (2004) found with a very modest regional data set for Italian milk prices that stationarity tests such as that of Dickey & Fuller (1979) could provide an effective way of defining the dimensions of a market, especially when there is a limit to the number of time series observations (Milosevic et al., 2018). One problem with that approach is that the long-run restrictions are also binding on the short-run, this provides one reason why the test based on the ECM may be preferred (Kanjilal Ghosh, 2017). Furthermore, the ECM as part of an *N* dimensioned system with *N* error correction terms can be coherently defined (Boswijk, 1992). While Kremers, Ericsson & Dolado (1992) have shown that tests based on the error correction term in a dynamic model should be more powerful than the ADF test. The preferred model reveals that possibly three regional prices can be considered exogenous. When the long-run structure is further investigated it is suggested that the Gulf Coast, the Mid West and the West Coast prices are cointegrating exogeneity for $\beta_{.1}$, $\beta_{.2}$ and $\beta_{.4}$ indicating that the prices are not responding to each other in the long-run and this does not conforms with the law of one price.

More, the efficacy of the method and further the findings on weak and cointegrating exogeneity imply why there is an issue for competitive behaviour and what is critical is this arises from the system as compared with the single equation methods (Kurita, 2018). Hence, a competitive case requires a market with (*N-1*) linear cointegration vector among no weak exogenous variable (Burke & Hunter, 2011). Where with weak exogenous variable this result fails, this implies any failure of the rank test has an implication of some market failure (Kurita, 2012; Kurita, 2018), this implies finding a weak exogenous variable is at inconsistency to a competitive market or what is termed by Forni (2004) a definition of a broad market. Also, the failure to find (*N-1*) linear cointegrating vectors further negates the possibility that the market is broad, something that is not confirmed by the single equation analysis.

5.1 Theoretical implication

The main theoretical contribution concerns the market definition and key structure of long-run price behaviour in the US gasoline market. This relationship has previously been discussed (Forni, 2004; Burke & Hunter, 2011; Hunter & Tabaghdehi, 2013; Kurita, 2012; Kurita, 2018) but rarely empirically investigated the US gasoline market. The findings propose a new line of research by exploring the potential relationship between regional gasoline prices in US. Having identified the gap, this study proposes a conceptual framework to understand the impact of long-run price distinction and information transparency on consumer welfare. Such a framework has not been tested before in business literature. The long-run price behaviour and market complicity are of interest in business research domains, but there is a shortage of empirical research. The present study combines conceptual foundations and methodological approaches to contribute to the price behaviour and exogeneity theories by constructing the study framework and model.

Within the scope of the stationarity and cointegration properties, gasoline market became the important perspective in every step for businesses and economies (Forni, 2004). Similarly, to have a competitive edge, gasoline market has become more important to have the competitive threshold within the demanding energy market by governments and authorities (Hunter & Tabaghdehi, 2013). Therefore, it is likely to say that in energy pricing literature, there is a need for additional research about the arbitrage in particular, concerning the market prices respond to each other in terms of both cointegrating and weak exogeneity in the long-run (Hunter & Tabaghdehi, 2014; Hunter et al. 2017; Kurita 2018).

One of the interesting theoretical contributions of this study can be found the long-run information plays crucial role in a competitive market. This study also contributes to market theory by drawing on the theories of market definition (Forni, 2004) to fill a gap in price leadership studies (Burke & Hunter, 2011) regarding the effect of price discrepancy on the market structure and consumer behaviour. The findings on weak exogeneity provide a comprehensive enlightenment of the gasoline market in US where it is not effectively functioning and one region is not reacting to the other regions prices, while cointegrating exogeneity implies a sub-regional reaction, this suggests to a review and adjustment in regulation (Chen et al., 2018; Fafaliou & Polemis, 2011, Rious & Rossetto, 2018) of the gasoline market to improve competition.

5.2 Practical implications

The findings offer suggestions on observed market behaviour in the long-run could be due to the geographical conditions or may be a reflection of the ownership of regional refinery capacity and their location across the US. Considering the empirical results, we are suggesting a change in the regulation of the gasoline market to enhance competition. This could be related to the tax breaks to extend the refinery and distribution capacity of smaller firms. In this respect similar conclusions may also be relevant to countries such as the UK where significant concentration in refinery ownership has come under enquiry especially following the fuel protests and related blockades of refineries in 2000.

The failure of the gasoline market mirrors to some extent the conclusions of Forni (2004) and this implies anti-trust authorities resists further concentration in the industry via merger or acquisition. However, in this case the findings follow from the subtler analysis related to the system of regional prices as compared with tests of stationarity that give rise to the conclusion the market may be competitive (Hunter & Tabaghdehi, 2013; (Milosevic et al., 2018). Hence, the imperfect regulation in the gasoline market would distort arbitrage and perfect competition where some form of regulation is required to address this in long-run (Chen et al., 2018; Fafaliou & Polemis, 2011, Kupper & Willems, 2010; Rious & Rossetto, 2018). Therefore, to increase the consumer's welfare it is required a competitive process to reduce the search and switching cost by subsidising information for consumers.

5.3 Limitations and suggestions for future study

As with all research, the current study has a number of limitations. This study is one of the limited scholarships to investigate whether the gasoline market is well defined in US and whether this is different in the multivariate context, considering the influence of price distinction on consumer behaviour and market leadership in the long-term.

The first limitation of this research concerns the location of the study. This research location concerns US, but the results might be different when applied to other countries. To overcome this limitation, future studies can evaluate the gasoline market structure in different country. Second, future research is recommended into supply and demand regimes in the gasoline market to measure long-run market failure by allowing the short-run parameters to switch in different regimes (Tabaghdehi, 2018).

Third, the Value-based pricing can be adopted in further studies to improve the profitability and value formation for firms and their customers in gasoline market (Toytari et al., 2017). Fourth, in future study the gasoline market behaviour can be investigated pre and post 2007 financial crisis to examine the relevant price behaviour by taking into account the global financial crisis.

Finally, to further investigate the gasoline market structure and the market completion associated with different companies, the future study could be extended to include gasoline company prices and search for weak exogenous price series with company data (Burke & Hunter, 2011). The authors encourage researchers to study the degree of competition by focusing on company activity in the market for future research.

6 References

Alm, J., Sennoga, E., & Skidmore, M. (2009). Perfect competition, urbanization, and tax incidence in the retail gasoline market. Economic Inquiry, 47(1), 118-134.

Al-sasi, B. O., Taylan, O., & Demirbas, A. (2017). The impact of oil price volatility on economic growth. Energy Sources, Part B: Economics, Planning, and Policy, 12(10), 847-852.

Angelopoulou, E., & Gibson, H. D. (2010). The determinants of retail petrol prices in Greece. Economic Modelling, 27 (6), 537-1542.

Bauwens, L., & Hunter, J. (2000). Identifying long-run behaviour with non-stationary data. Discussion Paper CORE, The Catholic University, Louvain-La Nueve DP 2000/43.

Boswijk, H. P. (1992). Cointegration, identification and exogeneity: Inference in structural error correction models. Amsterdam Thesis Publishers.

Brueckner, J. K. (1982). A test for allocative efficiency in the local public sector. Journal of public Economics, 19(3), 311-331.

Buccirossi, P. (2006). Does parallel behavior provide some evidence of collusion? Review of Law & Economics, 2(1), 85-101.

Burke, S. P., & Hunter, J. (2005). Modelling non-stationary economic time series: A multivariate approach. Palgrave, Basingstoke, UK.

Burke, S. P., & Hunter, J. (2011). Long-run, equilibrium price targeting. Qualitative and Quantitative Analysis in the Social Sciences, 5 (1), 26-36.

Burke, S. P., & Hunter, J. (2012). Arbitrage, market definition and monitoring a time series approach. Brunel University Working Paper, 12-20.

Cardebat, J. M., Faye, B., Le Fur, E., & Storchmann, K. (2017). The law of one price? Price dispersion on the auction market for fine wine. Journal of Wine Economics, 12(3), 302-331.

Cerqueti, R., Fanelli, V., & Rotundo, G. (2018). Long run analysis of crude oil portfolios. Energy Economics, in press.

Chen, X., Yang, H., & Wang, X. (2018). Effects of price cap regulation on the pharmaceutical supply chain. Journal of Business Research, in press.

Coglianese, J., Davis, L. W., Kilian, L., & Stock, J. H. (2017). Anticipation, tax avoidance, and the price elasticity of gasoline demand. Journal of Applied Econometrics, 32(1), 1-15.

Davidson, J. E. H., Hendry, D. F., Srba, F., & Yeo, S. (1978). Econometric modelling of the aggregate time series relationships between consumers' expenditure and income in the United Kingdom. Economic Journal, 88(253), 661-92.

De Vany, A. S., & Walls, D. (1999). Cointegration analysis of spot electricity prices: insights on transmission efficiency in the western US. Energy Economics, 21(5), 435-448.

Dickey, D. A., & Fuller, W. A. (1979). Distribution of the estimators for autoregressive time series with a unit root. Journal of the American Statistical Association, 74(366a), 427-431.

Doornik, J. A., & Hendry, D. F. (2009). OxMetrics Professional, Timberlake Consultants Press, London, UK.

Engle, R. F., & Granger, C. W. J. (1987). Cointegration and error correction: representation, estimation and testing. Econometrica, 55(2), 251-276.

Fafaliou, I., & Polemis, M. (2011). Market power in oil industry: The wholesale and retailing case. Economics Finance Notes, 1(1), 1–18.

Fama, E. F. (1991). Efficient capital markets: II. The journal of finance, 46(5), 1575-1617.

Fama, E. F. (1998). Market efficiency, long-term return and behavioral finance. Journal of Financial Economics, 49(3), 283-306.

Forni, M. (2004). Using stationarity tests in antitrust market definition. American Law and Economics Review, 6(2), 441-464.

Galeotti, M., Lanza, A., & Manera, M. (2003). Rockets and feathers revisited: An international comparison on European gasoline markets. Energy Economics, 25(2), 175-190.

Garner, C. A. (1981). Economic determinants of consumer sentiment. Journal of Business Research, 9 (2), 205-220

Giannini, C., & Mosconi, R. (1992). Non-causality in cointegrated systems: representation, estimation and testing. Oxford Bulletin of Economics and Statistics, 54(3), 399-417.

Giulietti, M., Otero, J., & Waterson, M. (2010). Pricing behaviour under competition in the UK electricity supply industry. Oxford Economic Papers, 62(3), 478-503.

Gordon, D. V., Hobbs, J. E., & Kerr, W. A. (1993). A test for price integration in the EC lamb market. Journal of Agricultural Economics, 44(1), 126-134.
Granger, C. W. J. (1969). Investigating causal relations by econometric models and cross-spectral methods. Econometrica, 37(3), 424-438.
Hendry, D. F. (1995). Dynamic econometrics. Oxford University Press on Demand, Oxford, UK.
Hendry, D. F., & Juselius, K. (2001). Explaining cointegration analysis: part II. Energy Journal, 22(1), 75-120.
Herzer, D., & Donaubauer, J. (2018). The long-run effect of foreign direct investment on total factor productivity in developing countries: a panel cointegration analysis. Empirical Economics, 54(2), 309-342.
Horowitz, I. (1981). Market definition in antitrust analysis: A regression based approach. Southern Economic Journal, 48(1), 1-16.
Hosken, D., & Taylor, C. T. (2004). Discussion of: Using stationarity tests in antitrust market definition. American Law and Economics Review, 6(2), 465-475.
Hunter, J. (1990). Cointegrating exogeneity. Economics Letters, 34(1), 33- 35.
Hunter, J. (1992). Tests of cointegrating exogeneity for PPP and uncovered interest rate parity for the UK. Journal of Policy Modelling, 14(4), 453-463.
Hunter, J., & Burke, S. P. (2008). Common trends, cointegration and competitive price behaviour. Economics and Finance Working Paper, Brunel University, (08) 07.
Hunter, J., Burke, S. P. & Canepa, A. (2017). Multivariate modelling of non-Sstationary economic time series. Palgrave Macmillan, London.
Hunter, J., Ioannidis, C., Iossa, E., & Skerratt, L. (2001). Measuring consumer detriment under conditions of imperfect information, Office of Fair Trading.
Hunter, J., & Simpson, M. (1996). Exogeneity and identification in a model of the UK effective exchange rate. Presented at the Econometrics Society European Meeting, Istanbul.
Hunter, J., & Tabaghdehi, S. A. H. (2013). Cointegration and US regional gasoline orices: Testing market efficiency from the stationarity of price proportions. Brunel University Working Paper, 13-03.
Hunter, J., & Tabaghdehi, S. A. H. (2014). Extracting long-run information from energy Prices: The role of exogeneity. Brunel University Working Paper, 13-19.
Johansen, S. (1992). Testing weak exogeneity and the order of cointegration in UK money demand data. Journal of Policy Modeling, Special Issue: Cointegration, Exogeneity and Policy Analysis, 14(3), 313-334.
Johansen, S. (1995). Likelihood-inference in cointegrated Vector Auto-Regressive models. Oxford University Press, Oxford, UK.
Johansen, S., Mosconi, R., & Nielsen, B. (2000). Cointegration analysis in the presence of structural breaks in the deterministic trend. Econometrics Journal, 3(2), 216–249.
Juselius, K. (1995). Do purchasing power parity and uncovered interest rate parity hold in the long-run- An example of likelihood inference in a multivariate times series model. Journal of Econometrics, 69(1), 178-210.

Kanjilal, K., & Ghosh, S. (2017). Dynamics of crude oil and gold price post 2008 global financial crisis–New evidence from threshold vector error-correction model. Resources Policy, 52(1), 358-365.

Kremers, J. J. M., Ericsson, N. R., & Dolado, J. J. (1992). The power of cointegration tests. Oxford Bulletin of Economics and Statistics, 54(3), 349-67.

Kristoufek, L. (2018). Are the crude oil markets really becoming more efficient over time? Some new evidence. Energy Economics.

Kupper, G., & Willems, B. (2010). Arbitrage in energy markets: Price discrimination under congestion. The Energy Journal, 31(3), 41-66.

Kurita, T. (2008). Common stochastic trends and long-run price leadership in the US gasoline market. Working paper WP-2008-003, Faculty of Economics, Fukuoka University, Fukuoka.

Kurita, T. (2018). A note on potential one-way policy instruments in cointegrated VAR systems. Economic Analysis and Policy, 58(1), 55-59.

La Cour, L. F., & Mollgaard, H. P. (2002). Market domination: Tests applied to the danish cement industry. European Journal of Law and Economics, 14(2), 99-127.

LecG Ltd. (1999). Quantitative techniques in competition analysis. Research paper No 17, Office of Fair Trading, London.

Markham, J. (1951). The nature and significance of price leadership. American Economic Review, 41(5), 891-905.

Maunder, P. (1972). Price leadership an appraisal of its quality in some british industries, The Business Economist, 4(3), 132-140.

Milošević, S., Markopoulos, J. P., Grahovac, J., & Ravić, A. (2018). Pricing benchmark in market definition: Theoretical background and practical application. in competition authorities in south eastern Europe, Springer, Cham.

Moral-Benito, E., & Seven, L. (2015). Testing W/weak exogeneity in cointegrated panels. Applied Economics, 47(30), 3216-3228.

Nishida, M., & Remer, M. (2018). Lowering consumer search costs can lead to higher prices. Economics Letters, 162(1), 1-4.

Ogbuabor, J. E., Orji, A., Aneke, G. C., & Charles, M. O. (2018). Did the global financial crisis alter the oil–gasoline price relationship? Empirical Economics, in press.

Parinandi, S., & Hitt, M. P. (2018). How politics influences the energy pricing decisions ofeElected public utilities commissioners. Energy Policy, 118(1), 77-87.

Polemis, M. L. (2012). Competition and price asymmetries in the Greek oil sector: An empirical analysis on gasoline market. Empirical Economics, 43(2), 789–817.

Polemis M. L., & Fotis, P. N. (2013). Do gasoline prices respond asymmetrically in the euro zone area? Evidence from cointegrated panel data analysis. Energy Policy, 56(1), 425-433.

Rahbek, A., Hansen, E., & Dennis, J. G. (2002). ARCH innovations and their impact on cointegration rank testing. Working paper, No 22, Centre for Analytical Finance, University of Copenhagen.

Ramberg, D. J., Chen, Y. H., Paltsev, S., & Parsons, J. E. (2017). The economic viability of gas-to-liquids technology and the crude oil–natural gas price relationship. Energy Economics, 63(1), 13-21.

Ravallion, M. (1986). Testing market integration. American Journal of Agricultural Economics, 68(1), 102-109.

Rious, V., & Rossetto, N. (2018). Continental incentive regulation. Electricity Network Regulation in the EU: The Challenges Ahead for Transmission and Distribution. Edward Elgar Publishing, 28-51.

Slade, M. E. (1986). Exogeneity test of market boundaries applied to petroleum products. Journal of Industrial Economics, 34(3), 291-304.

Smith, R. P., & Hunter, J. (1985). Cross arbitrage in the specification of exchange rate models. Economics Letters, 18(4), 375-376.

Stigler, G. J. (1947). The kinky oligopoly demand curve and rigid prices. Journal of Political Economy, 55(5), 432-449.

Tabaghdehi, S. A. H. (2018). Market collusion and regime analysis in the US gasoline market. Journal of Economics Structure, 7(1), 9.

Toytari, P., Keranen, J., & Rajala, R. (2017). Barriers to implementing value-based pricing in industrial markets: A micro-foundations perspective. Journal of Business Research, 76(1), 237-246

Trapani, L. (2015). Testing for exogeneity in cointegrated panels. Oxford Bulletin of Economics and Statistics, 77(4), 475-494.

Wright, C. J. (2017). Fundamentals of oil & gas accounting. PennWell Books, Tulsa, USA.

Appendix:

Table 1- Johansen trace test for cointegration

H_0 : rank ≤	Trace test	P-value
rank =0	226.673	[0.0000] **
rank =1	159.485	[0.0001] **
rank =2	115.337	[0.0012] **
rank =3	76.017	[0.0147] *
rank =4	48.471	[0.0437] *
rank =5	28.207	[0.0754]
rank =6	11.631	[0.1755]
rank =7	1.1499	[0.2836]

Note: * significant at the 5% level and ** significant at the 1% level.

Table 2- Test of Cointegration, Weak Exogeneity, Long-run Exclusion, Strict Exogeneity and Parallel Pricing of US Regional Gasoline Price

Hypothesis		Null ($r \leq 5$)	Statistics [p-value]
(WE)| r=5	P_{CA}	α_{1i}= 0, for i=1, …, 5	$\chi^2(5)$ = 18.872 [0.00]**
	P_{EC}	α_{2i}= 0, for i=1, …, 5	$\chi^2(5)$ = 11.359 [0.04]*
	P_{GC}	α_{3i}= 0, for i=1, …, 5	$\chi^2(5)$ = 5.125 [0.40]
	P_{LA}	α_{4i}= 0, for i=1, …, 5	$\chi^2(5)$ = 6.238 [0.28]
	P_{MW}	α_{5i}= 0, for i=1, …, 5	$\chi^2(5)$ =8.964 [0.11]
	P_{NE}	α_{6i}= 0, for i=1, …, 5	$\chi^2(5)$ =13.569 [0.02]*
	P_{RM}	α_{7i}= 0, for i=1, …, 5	$\chi^2(5)$ = 32.671 [0.00]**
	P_{WC}	α_{8i}= 0, for i=1, …, 5	$\chi^2(5)$ = 19.753 [0.00]**
(LE)| r=5	P_{CA}	β_{j1}= 0, for j=1, …, 5	$\chi^2(5)$ = 21.249 [0.00]**
	P_{EC}	β_{j2}= 0, for j=1, …, 5	$\chi^2(5)$ = 12.304 [0.03]*
	P_{GC}	β_{j3}= 0, for j=1, …, 5	$\chi^2(5)$ = 17.971 [0.00]**
	P_{LA}	β_{j4}= 0, for j=1, …, 5	$\chi^2(5)$ = 10.782 [0.05]
	P_{MW}	β_{j5}= 0, for j=1, …, 5	$\chi^2(5)$ = 26.335 [0.00]**
	P_{NE}	β_{j6}= 0, for j=1, …, 5	$\chi^2(5)$ = 10.869 [0.05]
	P_{RM}	β_{j7}= 0, for j=1, …, 5	$\chi^2(5)$ = 40.178 [0.00]**
	P_{WC}	β_{j8}= 0, for j=1, …, 5	$\chi^2(5)$ = 29.493 [0.00]**
Normalization (N) + (WE) P_{GC} | r=5		β_{ii}=1, for i=1, …, 5 $\beta_{ij}= 0$, for $\begin{cases} i = 1, \ldots, 5 \\ j = 1, \ldots, 5 \\ i \neq j \end{cases}$ α_{3i}= 0, for i=1, …, 5	$\chi^2(5)$ = 5.125 [0.40]
SE = (LE) + (WE)| r=5	P_{CA}	α_{1i}= 0, for i=1, …, 5 β_{j1}= 0, for j=1, …, 5	$\chi^2(10)$ = 35.633 [0.00]**
	P_{EC}	α_{2i}= 0, for i=1, …, 5 β_{j2}= 0, for j=1, …, 5	$\chi^2(10)$ = 20.717 [0.02]*
	P_{GC}	α_{3i}= 0, for i=1, …, 5 β_{j3}= 0, for j=1, …, 5	$\chi^2(10)$ =22.520 [0.01]*
	P_{LA}	α_{4i}= 0, for i=1, …, 5 β_{j4}= 0, for j=1, …, 5	$\chi^2(10)$ =30.611 [0.01] **
	P_{MW}	α_{5i}= 0, for i=1, …, 5 β_{j5}= 0, for j=1, …, 5	$\chi^2(10)$ =32.287 [0.00]**
	P_{NE}	α_{6i}= 0, for i=1, …, 5 β_{j6}= 0, for j=1, …, 5	$\chi^2(10)$ =19.658 [0.03]*
	P_{RM}	α_{7i}= 0, for i=1, …, 5 β_{j7}= 0, for j=1, …, 5	$\chi^2(10)$ =49.721 [0.00]**
	P_{WC}	α_{8i}= 0, for i=1, …, 5 β_{j8}= 0, for j=1, …, 5	$\chi^2(10)$ = 46.086 [0.00]**

Note: Weak Exogeneity (WE), Long-run Exclusion (LE), and Strict Exogeneity (SE). * significant at the 5% level and ** significant at the 1% level.