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Farm Production Costs, Producer Prices and Retail Food Prices in Greece: A Cointegration Analysis

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The relationship between farm production costs, producer prices and retail food prices has been quite often the subject of research. This study examines the existence of cointegrating relationships and the direction of causality between these variables in Greece. The data used refer to price indices of farm inputs and outputs for crop and livestock production and retail price indices for food and non-alcoholic beverages. The stationarity of the time series is examined using the alternative econometric tests of the literature. The Johansen procedure verifies the existence of a long run equilibrium relationship. Both, the Maximum Eigenvalue test and the Trace test confirm the existence of one only cointegrating relationship. Alternative formulations of the linear long run equilibrium relationship are examined within the Johansen context and the short and long run causality directions are investigated. It is found that in the short and long run, production costs and producer prices "influence" retail food prices. In addition to the estimated cointegrating relationship, the estimated Vector Error Correction Model provides information on the speed and adjustment process towards the long run equilibrium.

INTRODUCTION

The relationship between farm input prices and output prices is well established in theory. Supply and demand conditions in one market and its price changes can affect the prices of the other. Farm output prices and retail food prices are also connected through supply and demand conditions in their perspective markets and marketing margin costs.

These refer to transport, packaging, processing, etc., when not received by the first and final stage of the production and trading process. These are actually inflows and outflows of the intermediate

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stages (Wohlgenant, 2001). Changes in conditions of supply and demand of the initial or final stage have the effect of changing the prices of the intermediate stages that is, changing the marketing margin as well. Moreover, changes in the supply and demand conditions of various elements of the marketing margins will cause a decrease or increase of their respective prices and this will affect the prices at other stages. Initial changes in market conditions of any stage are caused by changes in productivity, international trade conditions and / or exchange rates, preferences, etc. In a macroeconomic level we can find the causes of changes in income, taxes and subsidies in one or more stages, as well as changes in parameters in monetary policy (Sephton, 1989).The overall effects of price changes at any level of the marketing chain depend on the elasticities of supply and demand in the various stages (Marsh, 1991).

Estimates and knowledge of the cost and price relationships between different stages of the production and trade chain can be particularly useful in economic forecasting and policy analysis. Equilibrium relationships, adjustment paths, and causal directions, provide information which can be used in impact analysis of policies and changes in supply and demand conditions. The objective of this study is to examine the existence of long run equilibrium relationships between farm production costs, producer prices, and retail food prices in Greece. Estimations of such relationships with the corresponding adjustment paths and causal directions are also objectives.

LITERATURE REVIEW

Engle (1978) studied the relationship between wholesale and retail prices of food products and Guthrie (1981) analyzed the relationship between general wholesale and retail price indicators. Both surveys suggest causality from lower to higher levels (retail prices). Larue (1991) found bidirectional relationship, searched for cointegrating relations and concluded that (contrary to the prevailing notion that output prices are more flexible than input prices) output prices are "weakly exogenous" in the model in the sense that although they are cointegrated, they don't respond systematically to the imbalance of input prices and retail prices.

Lolos, Chondrogiannis & Papapetrou (1998) investigated the causal relationship between farm input prices, producer prices and consumer food prices for Greece using data for the 1986 to 1997 period. They found long run equilibrium between these three variables and they concluded that a bidirectional causal relationship exists between consumer food prices and farm producer prices, a bidirectional causal relationship between farm input prices and producer prices and a unidirectional causal relationship from food prices to input prices.

Moss (1992) also used cointegration analysis to investigate whether the prices received by producers and the price they pay move together in the long run. He found no cointegrating relationship, implying that the effect of margin's compression between input costs and reduced selling price (Cost-Price Squeeze) cannot be rejected in the long run. If the prices the farmers receive and the prices they pay are cointegrated, the Cost-Price Squeeze effect is not sustained in the long run. This means that under the presence of inflation input prices are rising more than output prices, since farmers are price receivers and they are not able to pass higher input costs to consumers and thus they have to adjust the use of inputs and outputs, as the ratio of output / input decreases.

On the contrary, according to Campiche *et al.* (2006), the null hypothesis of cointegration between input and output prices cannot be dismissed. They suggested that prices received and prices paid by producers move on an one to one ratio and any cost increases pass into the next level in less than eight months on the average. Loizou *et al.* (1997) found no cointegrating relationship between prices paid and received by farmers in the Greek agricultural sector. They found that this can be explained by macroeconomic variables such as the domestic product, the general price level, and the supply of money. They used however twenty seven annual observations for the 1966-1993 period. Money supply and food prices in Greece at the retail level were found to be cointegrated in Ziotis & Papadas (2011). Katsouli *et al.* (2002) calculated the relative influence of producer prices on various consumer price indices. They found that the food price index absorbs the largest part of the impact of a rise in the producer price index within the first month. Tweeten (1980) considered that the terms of trade deteriorate for farming, as inflation increases, while Starleaf *et al.* (1987) found that under conditions of inflation agricultural output prices adjusted faster than input prices.

From a theoretical perspective it can be argued that farmers will gain (lose) after a rise in inflation if output prices are more (less) flexible than input prices. Chambers (1983) found that the estimated impacts caused by monetary factors (when the prices of certain products are more flexible than others) are affected by autocorrelation. In other words, the quantity of money is not neutral in the short run. It is worth noting that there are opinions that support the existence of "neutral" effects of inflation in terms of trade for farmers. Prentice & Schertz (1981) and Gardner (1979) did not find a statistically significant relationship between changes in the general price level and the relative price level of inputs and outputs in agriculture. A major weakness of these studies is the failure to distinguish between non expected and expected inflation (Falk, 1986).

METHODOLOGY

Unit root tests and cointegration analysis are performed in order to investigate the mechanism of adjustment between the three variables of farm input prices, producer prices and retail food prices in Greece. The stationarity properties of the three time series and their degree of integration are initially examined and then, the maximum likelihood method of Johansen is applied to determine whether there are long run equilibrium relationships between the three variables. Finally, the existence and direction of long-run and Granger short-run causality between the three variables is examined.

Stationarity of the three time series is examined using unit root tests for each series. The Augmented Dickey-Fuller test – ADF (1981) is used, together with the Phillips and Perron – PP (1988) and the Kwiatkowski *et al.* – KPSS (1992) tests. In the commonly used ADF test, the null hypothesis H_0 is that the series contains one unit root and the alternative that the series does not contain a unit root (i.e. stationarity). The testing procedure is followed using the three AR(n) models with a trend variable, for the three variables expressed here as

$$\Delta Y_t = \delta + \beta Y_{t-1} + \gamma t + \sum_{i=1}^{n} a_i \Delta Y_{t-i} + \varepsilon_t \tag{1}$$

It is essential to determine the appropriate number of lags (n) for each model and corresponding series. A small number of lags may result in over-rejection of $H_{0,}$ when it is true (i.e. increases the power of the test), while the use of a large number of lags may result in non-rejection of H_0, when it is not true (i.e. reducing the power of the test).

Ng and Perron (1995) propose a maximum limit of lags ρ_{max} and the running of the ADF regression with lags ρ = ρmax. If the absolute t-value of the coefficient of the last lag is greater than 1.6, then we set ñ = ñmax and we perform a unit root test. Otherwise we reduce the lags by one and repeat the process. Alternatively, Schwert (2002) suggested the selection of maximum lags in ADF tests to be based on the formula

$\rho_{max} = \text{int}\left[12\left(\frac{T}{100}\right)^{\frac{1}{4}}\right]$ (2) , where "int" denotes the nearest integer, which allows the number of maximum lags ρ to be an increasing function of the number of the sample's observations T. Then, the approach followed is the introduction of the maximum number of lags in the test regression (1) and the progressive elimination of terms with the longer lags, if their coefficients are statistically non-significant and/or the regression shows evidence of 1st or 2nd order residual autocorrelation based on tests used in dynamic models (the Lagrange Multiplier Test).The process is repeated until statistical significance with lack of autocorrelation is achieved.

Once the number of lags is adopted for each variable series, testing for the null hypothesis that the coefficient of the lagged variable in (1) is zero (existence of unit root in the series of the variable) against the alternative that the coefficient is negative, shows if the series of the variable is stationary (rejection of the unit root existence). Testing is performed for all three variables and if they are non-stationary, the process is repeated using their first differences. If the series of variables are non-stationary at their levels but stationary at their first differences, they are integrated of first order I(1) and we can test for the existence of cointegrating relationships using the Johansen procedure. The same generally holds if all variables are stationary at the same order of differences (second, third, etc.).

The process involves also the selection of the appropriate form of (1), in order to estimate and test the null hypothesis that the coefficient of the lagged term is zero. That means that the significance of the deterministic trend and the constant term in (1) is also examined and a specification including both, or one, or none of them is selected as results on stationarity are obtained. Depending on the step of the process for the selection of the specification, critical values based on the t-distribution, Φ1, Φ3, Fuller (1976), and Dickey & Fuller (1981) are used. A detailed description of the process can be found in Dolado, J., Jenkinson, T. and Sosvilla-Rivero, S. (1990), Enders W. (1995), and Perman, R. & Holden, D. (1995).

Cointegration refers to the long-run equilibrium relationship of certain variables, which means that although the time series of the variables may contain stochastic elements (i.e. they are not stationary), they will line in the long run and the difference between them will be determined by a certain relationship. In other words, the economic variables may have an independent course between them in the short-run (non-stationary), but if there are long paths (i.e. they are cointegrated), these must be taken into account through the specification of the error correction when causal relationships are analyzed or forecasting is conducted.

Based on the results of stationarity tests, the existence of cointegration of I(1) variables can be investigated using the Johansen tests which requires the use of a vector autoregressive system (VAR) and its conversion to a vector correction model (VECM). We consider the VAR system of three equations for the (3x1) vector Y of our variables:

$$Y_t = \sum_{i=1}^{p} A_i Y_{t-i} + \gamma + e_t \tag{3}$$

where each A_i is a diagonal (3x3) matrix of coefficients, γ is a (3x1) vector of constant terms (not necessarily the same as in (1)), and e the error terms. We convert (3) into a vector error correction model VEC which becomes:

$$\Delta Y_t = \sum_{i=1}^{p-1} \Gamma_i \Delta Y_{t-i} + \Pi Y_{t-1} + \upsilon_t \tag{4}$$

Each Γ_i matrix and the "equilibrium" or "impact" matrix Π are now (3x3) coefficient matrices with

$\Gamma_i = -\sum_{j=i+1}^{p} A_j$ and $\Pi = \sum_{i=1}^{p} A_i - I$ where υ is the error term vector and I is the identity matrix. In each of the three equations in (3) the error terms satisfy the usual assumptions and are not autocorrelated even though they can be correlated across equations.

Before proceeding to testing, it is essential to determine the appropriate number p of lags in the VAR model, i.e. its order. A common approach is to start with the number of lags used in the ADF tests and then apply one or more of the existing criteria.

If the rank r of Π is $r(\Pi) < 3$ (three being the number of variables we consider here), then the I(1) variables are cointegrated, with the number of linearly independent "cointegrating vectors" r determining the "degree of cointegration". If r = 3 then the variables would have been stationary at their levels to begin with, and the VAR model should be estimated since the VECM would be meaningless. Moreover, if r =

0 the variables are clearly non-cointegrated. Now there can be at most two cointegrating relationships (one less than the number of variables) depending on the rank being 1 or 2, and the VEC model should be estimated. If cointegration exists, a decomposition of Π such that $\Pi = \phi\psi'$ is possible, where ϕ and ψ are (3xr) matrices such that the linear combinations $\psi' \mathrm{Y}_{t-1}$ provide us with the r cointegrating relationships. The columns of ψ provide the cointegrating vectors i.e. the coefficients of variables in the cointegrating relationships. The rank of ψ is r, the degree of cointegration. The cointegrating relationship represents the long run equilibrium relationship between the variables, while the vector $\phi \mathrm{Y}_{t-1}$ provides deviations from equilibrium and the elements of ϕ are the adjustment speed coefficients.

With regards to the VAR model and the cointegrating vectors, Johansen argues that the above "standard" forms most often used in the literature (inclusion of constant terms but no trends as most often used in the literature) may not be sufficient. Inclusion of deterministic terms may be important in order to capture and demonstrate how variables and cointegrating relationships evolve over time. In a more general form the VEC model can be written as:

$$\Delta \mathrm{Y}_t = \phi(\psi' \mathrm{Y}_{t-1} + \gamma_1 + \theta_1 t) + \sum_{i=1}^{p-1} \Gamma_i \Delta \mathrm{Y}_{t-i} + \gamma_2 + \theta_2 t + \upsilon_t \qquad (5)$$

where the term in brackets gives us the cointegrating vectors and the terms after that are the VAR part of the VEC model. Again, γ_i's and also θ_i's are (3x1) vectors. Johansen considers the five alternative forms:

1: No constant terms or trends in both, the cointegrating vector sand the VAR part (i.e. $\gamma_1 = \gamma_2 = \theta_1 = \theta_2 = 0$).

2: Constant terms and no trends in the cointegrating vectors, and no constants or trends in the VAR part (i.e. $\gamma_2 = \theta_1 = \theta_2 = 0$).

3: Constant terms and no trends in both, the cointegrating vectors, and the VAR part (i.e. $\theta_1 = \theta_2 = 0$).

4: Constant terms and trends in the cointegrating vectors, constant terms but no trends in the VAR part (i.e. $\theta_2 = 0$)

5: No restriction set with regards to constants and trends in both, the cointegrating vectors and the VAR part. It becomes difficult to give economic interpretation to the results in this case, mainly because they imply constantly increasing or decreasing rates of change when using the variables in logarithmic terms.

It is argued that only forms 2, 3 and 4 are of interest (Cottrell, 2011) or that only forms 3 and 4 are worthy of testing (Franses, 1999). The first form is too restrictive while the fifth is rather unrealistic and despite its quantitative challenge, it's not considered satisfactory for economic analysis.

Johansen proposes actually to estimate forms 2, 3 and 4, and then test the null hypothesis of no cointegrating vector in these cases starting from form 2. If the null hypothesis is rejected for form 2, the null hypothesis is tested for form 3. If rejected again, form 4 is tested. If the hypothesis that there is no cointegrating vector is rejected in these three forms, then the next step is to test the null hypothesis that there is one only cointegrating vector starting from form 2 while following the same process and order with regards to the models and the number of cointegrating vectors. The process is repeated until the null hypothesis for the number of cointegrating vectors cannot be rejected. Then there is no reason to proceed further and the appropriate model is selected (Sjo, 2008). This is the process followed in this study for the specification of cointegrating vectors and the adjustment process accompanied by appropriate cointegration tests found in the literature.

We can determine also the long run and short run direction of causality. Two sources of causality can be found here. One is through the error correction term implied by the cointegrating vector, which refers to the long-term equilibrium relationship. The other is through the coefficients of the lagged differences (i.e. in the VAR part of the VEC model) which refer to the short-term dynamics. The suggestion that a variable x_k does not cause a variable x_j in the long run, is equivalent to a zero or insignificant error correction term. That is, the x_j variable does not react to the equilibrium errors and in other words is weakly exogenous. The suggestion that the variable $x_{\hat{e}}$ does not Granger cause the x_j variable in the short run, implies that the coefficients of the explanatory lagged differences are equal to zero. Short-run Granger causality is determined examining the joint significance of the lagged variables, applying a Wald test using the F or X^2 distribution.

ANALYSIS AND RESULTS

Quarterly data on price and cost indices for the period 2000-2012 provided by the Greek Statistical Authority are used. Price indices refer to our three variables, i.e. farm input prices (INPUT), farm producer prices (OUTPUT) and retail food prices (FOOD). The fifty two observations available refer to both crop and livestock production.

The maximum number of lags in (1) was selected as suggested by Schwert (2002) using (2). The adopted number of lags was determined as discussed, i.e. using progressive eliminations of longer lags with statistically non- significant coefficients and until also the estimation shows no evidence of first or second order residual autocorrelation, according to the LM correlation test. Then, the appropriate specification of (1) for the three series was selected following the procedure also discussed. It was found that for the input prices index (INPUT) and the producer prices index (OUTPUT), the inclusion of both a constant term and a deterministic trend in (1) were most appropriate at the 5% level of significance. For the food retail price index (FOOD) a constant term but no deterministic trend in (1) was adopted at the same level of significance.

The ADF tests show that all three series are non-stationary at their levels. The INPUT and OUTPUT variables are clearly stationary at their first differences - I(1) - at level of significance 5% and the FOOD variable is also I(1) at level of significance 6.3% and above. Given the proximity of the latter to the arbitrary 5% threshold often used and following a common practice in the literature for such cases, we considered all series I(1) and proceeded to cointegration analysis. Even though this decision is based on the ADF tests, there are also results from the Phillips-Perron (PP) and the KPSS tests supporting the conclusion that the three series are I(1).

In both the PP and KPSS tests the inclusion of a constant or deterministic trend does not depend on a process such as in the ADF test. The PP test implied that the FOOD series is I(1) at 5% level of significance when a constant term only is included or when no constant and no trend are included. In exactly the same cases, the OUTPUT series was I(1) too at 5%. The INPUT series was found I(1) at 5% when a constant only is included, when a constant and a trend is included and when both are absent.[1]

In order to proceed with the cointegration tests, the lag order of the VAR was first defined. Using as initial number of lags the suggested by Schwert (2002), five criteria were subsequently used to select the number of lags in the VAR. These are the Schwartz Information Criterion (SIC), the Hannan-Quinn (HQ) Information Criterion, the Akaike Information Criterion (AIC), the Final Prediction Error (FPE) method and the sequential modified LR statistic. Two of the tests, the SIC and HQ gave the same result that three lags should be selected. Two other tests suggested a bit different lag structure. (The Sequential modified LR test statistic - each test on 5% significance level - suggests two lags and the FPE method five lags). Only the AIC gave a largely different number of ten lags. Based on the above, we adopted three lags as both, the SIC and HQ suggested.

The suggested by Johansen procedure was applied in order to select the appropriate specification of VEC in (5) among the five alternative forms and the second model was selected (i.e. constant terms and no trends in the cointegrating vectors and no constants or trends in the adjustment process). Moreover, both the Trace-test and the Maximum-Eigenvalue test for this model reject the null hypothesis that there is no cointegrating vector and accept that there is at most one cointegrating vector (at 5% significance level). The critical values of McKinnon-Haug-Michelis (1999) and Osterwald-Lenum (1992), where used for all conducted tests. The exact results of cointegration tests and the procedure to select the appropriate VEC model are described in Table 1 of the Appendix.

The estimated elements of the cointegrating vector and their statistical significance provide after normalization with respect to the FOOD variable the following cointegrating relationship:

$$\underset{}{\text{FOOD}}= \underset{(6.77)}{0.54\ \text{OUTPUT}} + \underset{(3.29)}{0.16\ \text{INPUT}} + \underset{(8.81)}{31.55} \tag{6}$$

All coefficients of the relationship are significant at 5% (t-values in parentheses). The model shows that retail food prices (FOOD) in the long run move in the same direction with farm input (INPUT) and farm output (OUTPUT) prices in the Greek agriculture. It follows that in equilibrium, an increase of farm output prices by one unit increases the food price index food 0.54 units, while an increase of input prices by one unit increases the food price index by 0.16 units.

The estimated long run equilibrium relationship provides the Error Correction Model (ECM) as:

$$(\text{ECM})_{t-1}=(\text{FOOD})_{t-1}-0{,}54(\text{OUTPUT})_{t-1}-0{,}16(\text{INPUT})_{t-1}-31{,}5.$$

Estimation of the VECM provides also the adjustment process of the three variables and the adjustment speed coefficients ϕ' mentioned in the decomposition of Π. The system of three equations becomes:

$$\begin{bmatrix} \Delta\text{FOOD} \\ \Delta\text{OUT} \\ \Delta\text{IN} \end{bmatrix} = \begin{bmatrix} -0.55 \\ 1.08 \\ 0.05 \end{bmatrix} \left(FOOD_{t-1} - 0.54OUT_{t-1} - 0.16IN_{t-1} - 31.5\right) + \begin{bmatrix} 0.13 & 0.22 & -0.16 \\ 0.6 & 0.33 & 0.55 \\ 0.11 & 0.1 & 0.63 \end{bmatrix} \begin{bmatrix} \Delta FOOD_{t-1} \\ \Delta OUT_{t-1} \\ \Delta\text{IN}_{t-1} \end{bmatrix}$$

$$+\begin{bmatrix} 0.43 & -0.11 & -0.05 \\ 0.14 & -0.43 & 0.50 \\ 0.01 & 0.06 & -0.15 \end{bmatrix}\begin{bmatrix} \Delta FOOD_{t-2} \\ \Delta OUT_{t-2} \\ \Delta \mathrm{IN}_{t-2} \end{bmatrix}+\begin{bmatrix} -0.1 & -0.08 & -0.11 \\ 1.12 & -0.58 & 0.48 \\ 0.03 & 0.05 & 0.07 \end{bmatrix}\begin{bmatrix} \Delta FOOD_{t-3} \\ \Delta OUT_{t-3} \\ \Delta \mathrm{IN}_{t-3} \end{bmatrix}$$

where ΔFOOD = $FOOD_t$ – $FOOD_{t-1}$ while $\Delta FOOD_{t-i}$ = $FOOD_{t-i}$ – $FOOD_{t-i-1}$ and similarly for the other variables.

Table 2 of the Appendix shows the results of Granger short run and the long run causality testing. Using the X^2 distribution critical values at 5%, the Wald test implies that in the short run farm output prices Granger cause retail food prices and in addition, farm input prices and output prices jointly, also Granger cause the retail food prices. No other short run causality direction between the variables is established at 5% by the Wald test. The t-values of $(ECM)_{t-1}$ show that from the three possible combinations of long run causality directions only one is significant at 5%. We conclude that in the long run, farm input prices and farm output prices cause the retail food prices. The adjustment coefficient of the FOOD variable which is the only significant at 5%, shows that 55% of any disequilibrium between the retail food prices and the other variables in a quarter is corrected within next quarter. This is a rather speedy adjustment and no other long run causality was established.

CONCLUSIONS

We have examined the relationship between farm input prices, output prices, and retail food prices in Greece. The stationarity properties of the three time series were examined and cointegration analysis was conducted using quarterly data for the 2000-2012 period. There is strong evidence, supported by widely used testing procedures, that the series are not stationary at their levels but they are stationary at their first differences. This, despite the fact that some different tests with different arbitrary assumptions and specifications may lead to different and conflicting results. Cointegration analysis was conducted using the Johansen procedure that allows for the specification of the VECM (i.e. selection of a constant term vector and/or a deterministic trend vector in the cointegrating relationships and the VAR part which describes the adjustment process towards the long run equilibrium). No constant or trend was included in the VAR part but constant was included in the cointegrating relationship.

Both, the Maximum Eigenvalue test and the Trace test concluded that there is only one cointegrating vector and cointegrating relationship, which was also estimated as the long run equilibrium relationship between the three variables. The three variables are positively and significantly related in their long run equilibrium. Moreover, the error correction model shows the degree of disequilibrium in the short run and correlates changes in the food price index with changes in the output and input price indices and the equilibrating error of the previous period with the long-run equilibrium. The results showed a small lag in the adjustment of the food price index to changes in producer and farm input prices. Estimation of the error correction model shows that retail food prices are moving towards restoration of equilibrium (endogenous variable), while the farm output prices and input prices are characterized by weak exogeneity.

The short-term dynamics of the model shows that there is unidirectional Granger causality from farm output prices to retail food prices. When considered jointly, farm input and farm output prices again Granger cause the retail food prices. In the long run, there is unidirectional causality from farm output and input prices towards food prices. The results of statistical tests for both types of causality, short-term (Wald test through chi squared statistics) and long - term (through t-statistics), showed no further causal relationships between the variables. In other words, changes of producer prices in Greece have a direct impact on retail food prices and changes of farm input prices with simultaneous changes of producer prices, in the short and long run contribute to changes of retail food prices.

The estimated VECM and the significant causal directions found, provide information useful in forecasting and evaluating impacts of policies that target prices or events that exogenously influence them. No other than the above causal relations were found indicating that such price impacts do not exist (e.g. no effect from farm output prices to input costs, no effect from retail food price changes on producer and input prices) and this should be taken into account. However, found Granger short run causality as well as its absence, should be considered with caution due to its limitations. Beyond indications, they provide the information of which variables can be used to forecast others.

Similar research can be conducted for specific products and more stages of the production and marketing chain. One issue that has gained some importance in the literature and should be taken under consideration in similar studies is the possibility of non-linearities in the cointegrating relationships. Obviously, this becomes even more important as the number of variables considered increases. The usual threshold autoregressive procedure (TAR) has its shortcomings and is suitable for two variables only. The use of more sophisticated non-linearity tests for more variables and cointegrating relationships is needed, since the use of tests for linear cointegration and if positive the subsequent estimation of non-linear cointegrating relationships, has obvious conceptual problems. The limited so far use of artificial neural networks in combination with the available probabilistic tests for stationarity and cointegration has been promising, but the extension to more than two variables remains a challenge. A further research challenge is also the possibility for non-linearities in the adjustment process and the variable speeds of adjustment.

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Note

1. It is not surprising that different tests and specifications may yield different results. In the other specifications of PP and KPSS, stationarity at levels or the same level of differences is not accepted.

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APPENDIX

Table 1
Selection of the appropriate form of VECM and determination of number of cointegrating vectors
(The critical values of MacKinnon-Haug-Michelis (McK/H/M)) and Osterwald-Lenum (O-L) at 5% level of statistical significance are used)

Step 1: VECM form no 2

Hypothesized No. of CE(s)	*Trace Statistic*	*0.05 CriticalValue*	*Max-Eigen statistic*	*0.05 CriticalValue*
None	55.23	35.19 (McK/H/M) 34.91 (O/L)	35.64	22.29(McK/H/M) 22(O-L)

Rejection of hypothesis that there are no cointegrating vectors

Step 2: VECM form no 3

Hypothesized No. of CE(s)	*Trace Statistic*	*0.05 Critical Value*	*Max-Eigen statistic*	*0.05 Critical Value*
None	38.54	29.79 (McK/H/M) 29.68 (O/L)	28.63	21.13 (McK/H/M) 20.97(O-L)

Rejection of hypothesis that there are no cointegrating vectors

Step 3: VECM form no 4

Hypothesized No. of CE(s)	*Trace Statistic*	*0.05 Critical Value*	*Max-Eigen statistic*	*0.05 Critical Value*
None	54.25	42.91 (McK/H/M) 42.44 (O/L)	36.11	25.82 (McK/H/M) 25.54(O-L)

Rejection of hypothesis that there are no cointegrating vectors.

Step 4: VECM form no 2

Hypothesized No. of CE(s)	*Trace Statistic*	*0.05 Critical Value*	*Max-Eigen statistic*	*0.05 Critical Value*
At most 1	19.59	20.26 (McK/H/M) 19.96 (O-L)	10.24	15.89 (McK/H/M) 15.67(O-L)

The hypothesis that there is at most one cointegrating vectors in model Íï 2 is accepted and the test procedure stops at this point.

Table 2
Short-run and long run Granger causality tests

	VEC Granger Causality/Block Exogeneity Wald Tests Short run causality Excluded variables				*Weak exogeneity test (Long run causality)*
	Δ(FOOD)	*Δ(OUTPUT)*	*Δ(INPUT)*	*All*	*ECM_{t-1}*
Dependent variables		χ^2-stat			t-stat
Δ(FOOD)		18.85*	3.63	21.02*	-4.3*
Δ(OUTPUT)	2.57		2.84	5.7	1.53
Δ(INPUT)	0.31	1.91		3.34	0.24

- The null hypothesis that the lagged coefficients of the variable ΔOUTPUT in the VECM equation of ΔFOOD are equal to zero, is rejected due to the high value of χ^2 statistics. This means that the output price index Granger causes the food price index in the short run.
- The null hypothesis that the lagged coefficients of the variables ΔINPUT and ΔOUTPUT in the VECM equation of ΔFOOD are jointly equal to zero, is rejected due to the high value of χ^2 statistics. This means that output and input price indices jointly Granger cause, in the short run, the food price index.
- The high value of t statistics of FOOD's adjustment coefficient, leads to the rejection of the null hypothesis that it equals to zero. This means that the variable FOOD is influenced by OUTPUT and INPUT in the long run.
- No other causal relationship seems to exist, as the null hypothesis of no causality (Granger short run or long run) is accepted in all other cases, since the values of χ^2 and t statistics are very low. This means that each of the variables OUTPUT and INPUT are block exogenous to the other two.