*Theoretical and Applied Economics*
*Volume XXIII (2016), No. 1(606), Spring, pp. 15-40*

# Analysis of the causal link between wages and prices in UK

**Adriatik HOXHA**
University of Prishtina
adriatik.hoxha@gmail.com

**Abstract.** *As a matter of fact, the consensus of empirical evidence on the wage-price causal relationship reveals that there are two opposing groups of economists supporting conflicting hypotheses with respect to the flow of causality. Equally importantly, the literature review suggests that there is at least some consensus in the fact that inferences of researchers depend on the sample length, type of data employed, applied econometric model, or at the same time the relationship may be subject to the dynamics of economic cycles. In the light of these arguments, this paper conducts an empirical investigation of the wage-price causal relationship in UK by utilizing VAR and VECM models. Prior to designing and estimating econometric models the relevant stationarity tests for the wage, price and productivity variables have been performed. In summary, all three time series data are non-stationary and thus need to be differenced once in order to render them stationary. Correspondingly, the relevant cointegration tests have been performed and they provide robust evidence in support of a strong cointegration relationship between wages and prices. Additionally, respective restrictions on the parameters of estimated models have also been applied in order to derive the most parsimonious model. Regardless of the fact that VAR models tentatively indicate unilateral causality running from prices to wages, the VECM analysis only suggests a strong cointegration relationship and negates short-run causality in any direction. Accordingly, the estimated models have been subjected to diagnostic testing procedures, and these tests firmly indicate that estimated results are statistically robust. At the same time the restricted VECM model provides estimate on the basis of which it can be argued that the assumption of rational expectations in the wage-price relationship is perfectly valid.*

**Keywords:** Granger Causality, Cointegration, VAR, VECM.

**JEL Classification:** C39, E31, J30.

## 1. Introduction

Obviously, the modern analysis of philosophical discussion of causality began in the 18th century with Hume (1739). He made the scientific hunt for causes possible, by freeing the concept of causality from the metaphysical chains that his predecessors had used to pin it down. Furthermore, Haavlemo (1994) has also contributed in advancing the causality analysis by emphasizing that economic theory must be always formulated in stochastic terms. Over time, the applicability of causality concept has been ever increasingly used in social sciences as well as in the field of economics. As a perfect illustration of this is Granger (1969) paper "*Investigating Causal Relations by Econometric Models and Cross Spectral Methods*". In the same fashion, the issue of causal relationship between wages and prices has been intensively discussed in the literature. Nevertheless, despite enormous empirical efforts that have been invested in resolving the issue on who the cause is and who the effect is, the consensus is still far from being reached. In fact, there are two groups of economists. The first group argues in favor of hypothesis that causality runs from wages to prices, while the second one argues that causality runs from prices to wages. In summary, the evidence from literature is still conflicting and there is empirical evidence in support of both hypotheses.

The aim of this paper is to analyze empirically the pattern of causality in United Kingdom (UK). The paper is organized as follows: s*ection 2* reviews the literature on causality, *first*, literature on causality from the theoretical perspective, and *second*, focuses on empirical studies that have specifically examined causality between wages and prices; *section 3* explains the methodology that has been utilized in examining the causal relationship; s*ection 4* describes the variables and data that have been employed in this study, as well as the results of stationarity tests; *section 5*, presents Vector Autoregressive (VAR) model analysis and respective robustness checks; *section 6*, presents *Vector Error Correction Model (VECM)* analysis as well as diagnostic tests; finally, *Section 7* concludes by summarizing the main findings.

## 2. Review of the causal relationship

The purpose of this review is to present some theoretical definitions, characteristics and arguments on causality, in general, and on the wage-price causal relationship, in particular. In the first place, causality is a relevant concept both in natural and social sciences. As it has already been emphasized, the modern analysis of philosophical discussion of causality began in the 18th century with Hume (1739). In his view, causality is a regular succession of event-types: one thing invariably following another. His definition of causality runs as follows: "*We may define a CAUSE to be 'an object precedent and contiguous to another, and where all the objects resembling the former are placed in like relations of precedence and contiguity to those objects, that resemble the latter*". In fact, it was the 20th century and especially its last decades that saw its gained prominence in economics. Certainly, one of the most prominent modern studies on causality analysis in economics was conducted by Granger (1969) in the seminal paper "*Investigating Causal Relations by Econometric Models and Cross Spectral Methods*".

An important follow-up analysis of causality was carried out by Ashley et al. 1980, who had analyzed causality between advertising and aggregate consumption. They provide the following definition of causality: *"Let $\Omega_n$ represent all the information available in the universe at time n. Suppose that at time n optimum forecasts are made of $X_{n+1}$ using all the information in $\Omega_n$ and also using all of this information apart from the present values of $Y_{n-j}$, $j \geq 0$ of the series $Y_t$. If the first forecast, using all the information, is superior to the second, than the series $Y_t$ has some special information about $X_t$ not available elsewhere, and $Y_t$ is said to cause $X_t$*".

Importantly, is is very well understood in economics is that existence of a statistical relationship between two variables does not prove causality or direction of influence. Furthermore, in context of time series data, it may be possible to exploit the fact that time does not run backwards (so called "*time arrow*"). This relies on assertion that future cannot cause the past, and it is an *a priori* and fundamental feature of the way in which one orders its experience and not either an observed regularity or an analytic truth, (Gilbert, 2004). Table 2.1 provides a short summary of some studies that have examined in depth the causality issue in economics. Certainly, these studies can relatively encompass the significant developments in recent years.

**Table 2.1.** *A summary of some studies on causality presented in chronological order*

| Studies | Title | Context/Method |
|---|---|---|
| Ashley, Granger and Schmalensee (1980) | Advertising and Aggregate Consumption | Granger causality; Box-Jenkins technique |
| Sims (1999) | Granger Causality | Definitions; causality and exogeneity. |
| Jung and Seldon (1995) | The Macroeconomic relation between Advertising and consumption | Granger causality, Error Correction Model; |
| Gilbert (2004) | Economic Causality | Economic causation, intervention and exogeneity; VAR modeling practice; |
| LeRoy (2004) | Causality in Economics | Formal analysis of causal relations; graphical analysis; definitions on causality. |
| Andersson (2005) | Testing for Granger Causality in the presence of measurement errors | Problems of Granger-tests; consequences on forecastability. |

**Empirical facts on the wage, price and productivity relationship** – Undoubtedly, the issue of causality between wages and prices is one of the central questions in macroeconomics. The purpose of this review is to identify the key ideas or facts explaining the causal relationship between wages and prices. Certainly, it is sensible to assess what has been addressed so far on the relevant questions and problems related to the analysis of the relationship between wages and prices. There have been a number of studies that have analyzed the wage-price relationship, and in fact most of those studies have employed US data. Table 2.2 presents a summary of relevant studies on this relationship. The available studies focusing on the wage-price causality have used various methodologies and can be broadly divided into two groups. The *first group* of studies focuses on estimation of the wage and price causal effects by using data from various economic sectors, whereas the *second group* estimates the effect of wages on inflation by using aggregate (national) level data. Alternatively, with regard to the direction of effect the empirical studies can be divided into two groups. The *first group* of studies provides evidence in favor of hypothesis that causality runs from wages to prices, whereas the *second* group suggests that causality runs from prices to wages.

**Table 2.2.** *A summary of some studies on the wage, price and productivity relationship presented in chronological order*

| Studies | Title | Context/Method |
|---|---|---|
| Moschos (1983) | Aggregate Price Responses to Wages and Productivity Changes: Evidence from U.S. | Error Correction Model (ECM); Instrumental Variable (IV); |
| Emery and Chang (1996) | Do Wages Help Predict Inflation? | Granger causality ECM (Error Correction Model) |
| Palley (1999) | The U.S. Inflation Process: Does Nominal Wage Inflation cause Price Inflation, Vice-versa, or neither | Granger Causality; |
| Hess and Schweitzer (2000) | Does Wage Inflation Cause Price Inflation | Granger causality; ECM (Error Correction Model) |
| Garcia and Restrepo (2001) | Price and Wage inflation in Chile | ECM (Error Correction Model) |
| Jonsson and Palmqvist (2004) | Do higher wages Cause Inflation? | Two Sector Dynamic General Equilibrium (DGE) Model |
| Strauss and Wohar (2004) | The linkage between, prices wages and productivity: a panel study of manufacturing industries | Granger Causality; Panel Model; |
| Lemos (2004) | The Effect of Minimum Wage on Prices | Review of empirical research |
| Pu, Flaschel and Chihying (2006) | A Causal Analysis of the Wage-Price Spiral | Granger causality VAR (Vector Autoregressive) Model |
| Goretti (2008) | Wage-Price setting in New EU Member States | ECM (Error Correction Model); and Panel Model; |

A common feature of most of these studies is that many researchers have utilized the Granger-causality concept. Regarding econometric models applied in examining the long-run relationship between wages and prices, the review of literature suggests that it is the *Error Correction Models (ECM)* that dominates over alternative econometric methods. While it is commonly acknowledged in the literature that wages and prices move strongly together, Hess and Schweitzer (2000) argue that there is a sharp division amongst economists on whether wages cause prices or vice-versa. In order to explain such a causal relation, economists very often use the "Granger-causality" by examining whether the lagged values of one series (say wages) have a significant in-sample explanatory power for another variable (say prices). Additionally, both variables may Granger-cause one another, in which case one can conclude only that both economic series are determined simultaneously. If this is the case, the researcher may be unable to infer that one series has independent causal effect on the other. Frequently, the issue becomes more complex if variables in question are cointegrated, which is the case when the levels of the series move together over the long-run, even though the individual series are best modeled in growth terms. In that case, the researcher must be careful to include the error correction terms in Granger-causality tests so as to allow the series to catch up with one another. The significance of the ECM terms in Granger-causality tests simply reflects the fact that the series in question are driven to return to a long-run equilibrium relationship that it is non-causal. In addition to this, the researchers conclusions on the causal relationship often depend on the sample length, the number of explanatory variables used (including the number of lags of each variable) and in particular the measure of prices used, (Hess and Schweitzer, 2000).

Correspondingly, Emery and Chang (1996) empirically highlight the fact that significance of Granger causal relationship also depends on the choice of price series, and it is relevant to any researcher to avoid data mining whilst designing econometric models. In addition to this, Lemos (2004) argues that a fundamental reason why there has been a lack of evidence in favor of hypothesis that wages cause prices may be the fact that international literature has mainly utilized the data from US where the price effects are small. The selection of different variables may also play a significant role on the strength of results as well. For example, money supply indicators are often found to contain essential information for forecasting the future behavior of prices, and that needs to be considered as it may ultimately improve the robustness of model. Above all, when analyzing the causal relation between wages and prices, it is relevant to control for labor productivity, i.e. supply effects. Finally, it is important to emphasize Palley (1999) argument that causal relationship also varies through business cycles, i.e. causality order between prices and wages may alter over time. With all these facts in mind, next the focus shifts on methodological issues.

## 3. Methodology

Generally speaking, the biggest challenge in empirical research is to design a model which truly represents a certain data generating process (DGP) or economic phenomena. Potential presence of cointegration relationship between two or more variables not only makes harder, but certainly it makes more complex and challenging the process of model building. Regardless of the fact that various econometric models often produce highly significant parameters, it is the regression diagnostics, in particular the presence of autocorrelation, non-normality or ARCH that consequently cast serious doubts on the statistical and/or theoretical robustness of certain econometric models. For this reason, it is this limitation of remedying these post regression issues that necessitates application of more sophisticated models that are able to analyze more adequately complex relationships, such as that between prices and wages. Certainly, the VAR and VECM models are frequently applied in examining models with more than one endogenous variable. With this in mind, the aim of this study is to examine whether the causal relationship between wages and prices in the UK holds, in what directions it flows, is it statistically robust in fact, and is it in compliance with prior theoretical expectations.

*Mathematical relationship of prices, wages and productivity* – can be expressed in various functional forms. *First*, wage can be expressed as a function of price and marginal productivity of labor, i.e. $W = P * MPL$ or $W = f(P, MPL)$, where, W-wages, P-prices, and MPL - productivity. *Second*, price can be expressed as a function of wage and productivity, i.e. $P = W / MPL$ or $P = f(W, MPL)$. *Thirdly*, real wage (wages/prices) can be expressed as a function of productivity, i.e. $W / P = MPL$ or $W / P = f(MPL)$. In addition to this, one may transform these equations into natural logarithms, thus obtaining the following forms: *first*, ($\ln W = \ln P + \ln MPL$), i.e. wage equation indicates that wages are positively related to prices as well as marginal productivity of labor; *second*, (ln P = ln W – ln MPL), i.e. price equation indicates that prices are positively related to wages and negatively related to productivity, and *third* (ln(W/P) = ln MPL), i,e, real wages are positively related to productivity.

In this study wages and prices will be treated as endogenous variables due to the fact that when they enter the model their values are determined from within the model or the system of equations. In fact, there are numerous studies that have explicitly studied price wage causal relationship, (see for example Moschos, 1983; Emery and Chang, 1996; Palley, 1999; Hess and Schweitzer, 2000; DeGrauwe, 2003; Strauss and Wohar, 2004). Other variables may also be considered and included in the model. Nevertheless, increasing the number of variables and equations does not necessarily lead to a better model as by doing so it becomes harder to capture the dynamic and inter-temporal relations between relevant variables due to the loss of power. As a matter of fact, in some forecast comparisons univariate time series models were found to outperform large scale econometric models. Specifically, Lütkhepohl and Krätzig (2004) suggest that a possible reason for the failure of larger models is their insufficient representation of the dynamic interactions in a system of variables.

In contrast to wages and prices, productivity will be set as an exogenous variable as its value is determined outside the model. In the first place, it is well known from the Solow (1959) model that output depends on the level of technology, capital and labor. In addition to these factors one may also add human capital and land as additional factors of production, which subsequently also have significant impact on productivity. Furthermore, there are a number of studies that have comprehensively examined the productivity and its dynamics over time. Additionally, Smolny (2000) provides an empirical review on the sources of productivity growth by employing German sectoral data, with particular emphasis on allowing for inter-industry spillovers and scale economies at the aggregate level, as well as for scale economies associated with human capital at the sectoral level. Additionally he argues that business cycle affects observed productivity changes in the short-run and in the long run. Furthermore, Stiroh (2001) analyzes productivity growth by examining the key distinctions between the neoclassical and new growth theories. In his analysis of the neoclassical view, the exogenous technical progress drives long-run productivity growth as capital suffers from diminishing returns. In contrast, the new growth models yield long-run growth endogenously, either by avoiding diminishing returns to capital or by explaining technical progress internally. On the other side, Doraszelski and Jaumandreu (2013) examine relation between R&D and productivity, and their study provides account of endogenous productivity growth. Thus, on the basis of these facts, there is little doubt that productivity is determined outside the model.

*Applied econometric models* –this study will utilize two models, *first*, it will present VAR analysis, and s*econd*, VECM analysis. Prior to estimating these models it will also examine the respective model selection criteria for determining the lag order and/or lagged differences, and in the case of VECM also test for the rank of cointegration.

Nonetheless, taking into account space limitations only the relevant results will be presented in very concise way.

## 4. Data

Having already examined and determined mathematical equations as well as selected econometric models that will be applied in this study, the focus now shifts on explanation of data that will represent respective variables as well as conduct the analysis of their stationary properties. Specifically, this study will employ quarterly data covering period 1996:Q1-2007:Q4. *First*, Wage (W) variable represents *Labor Cost Index (LCI)* quarterly data, i.e. wages and salaries in industry and services (excluding public administration), nominal value, seasonally adjusted and adjusted data by working days. *Second*, Price (P) variable represents *Harmonized Index of Consumer Prices (HICP),* quarterly data. *Third*, Productivity (Q) variable is represented by the quarterly index representing *person based labor productivity* for total economy at constant prices (fixed composition), seasonally adjusted, not working day adjusted, total, ECU/euro, index. Hereinafter, wage, price and productivity variables are denoted as WUK, PUK and QUK, respectively. The source of data for all three variables is EUROSTAT. Detailed description of all variables has been presented in Table A4.1 in appendix.

For the purpose of conducting adequate and meaningful regression analysis it is necessary to employ graphical and formal stationarity (unit root) tests for the respective time series data. In Figure A4.1 in appendix the plots of log-levels and first difference of log-levels have been presented. Obviously, the visual analyses of plots of levels clearly indicate that time series data may not be stationary, i.e. time series data are integrated of order 1 or I(1), and that deterministic trend may be present in the levels of the respective data. In contrast, the first difference of log-levels of data clearly indicate stationarity, i.e. time series data are integrated of order zero or I(0). There are several formal unit root tests available such as Augmented Dickey-Fuller (ADF), Schmidt-Phillips, Phillips-Perron test for processes with level shift or Kwiatkowski, Phillips, Schmidt and Shin (KPSS) tests, (Lütkepohl and Krätzig, 2004). Taking into account the fact that plots of the time series data under consideration indicate no major disturbances for the sample period, formal unit root analysis will rely on ADF test procedure. In simple form the Augmented Dickey-Fuller (ADF) unit root test can be expressed as,

$$\Delta y_t = \phi y_{t-1} + \Sigma^{p-1}_{j-1} \alpha^*_j \Delta_{yt-j} + \mu_0 + u_t \qquad (4.1)$$

where $\varphi = -\alpha(1)$ and $\alpha^*_j = -(\alpha_{j+1} + \cdots + \alpha_p)$. In this model we wish to test the pair of hypotheses $H_0$: $\varphi = 0$ versus $H_1$ :$\varphi < 0$. The ADF test statistic is based on the t-statistic of the coefficient φ from an OLS estimation of above written equation, (Fuller, 1976; Dickey and Fuller, 1979. It does not have an asymptotic standard normal distribution, but it has a nonstandard limiting distribution. Critical values have been obtained by simulation, and they are available, for instance, in Fuller (1976) and Davidson and MacKinnon (1993). It turns out, however, that the limiting distribution depends on the deterministic terms that have to be included. Therefore, different critical values are used when a constant or linear trend term is added in. On the other hand, including seasonal dummies in addition to constant or linear trend does not result in further changes in the limiting distribution, (see Note 1 of Table 4.1). In these tests a decision on the AR order or, equivalently, on the number of lagged differences of $y_t$ has to be made. This choice may be based on the model selection criteria *(*AIC – Akaike Information Criterion; FPE – Final Prediction Error; HQC – Hannan-Quinn Criterion; and SC – Schwarz Criterion; Lütkhepohl and Krätzig, 2004), or a sequential testing procedure may be used that eliminates insignificant coefficients sequentially starting from some high-order model (Ng and Perron (1995). In addition to this, the suggested numbers of lagged differences by respective model selection criteria have been estimated and are presented in Table A4.2 in appendix.

**Table 4.1.** *Augmented Dickey-Fuller (ADF) test with one and zero lagged differences*

| Variable | $\mu_0$ | | $\mu_0 + \mu_1$ | | $\mu_0$ + sd | | $\mu_0 + \mu_1$ + sd | |
|---|---|---|---|---|---|---|---|---|
| lag diff | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| **LWUK** | -0.43 | -0.47 | -2.92 | **5.60 | -0.41 | -0.47 | -2.75 | **-5.38 |
| **LPUK** | 2.03 | 0.47 | 0.38 | -1.73 | 2.29 | 1.84 | 0.67 | 0.38 |
| **LQUK** | -1.28 | -1.23 | -1.49 | -2.10 | -1.22 | -1.15 | -1.46 | -2.00 |
| **DLWUK** | **-7.99 | **-13.7 | **-7.92 | **-13.5 | **-7.69 | **-13.4 | **-7.62 | **-13.2 |
| **DLPUK** | **-4.74 | **-14.7 | **-5.22 | **-15.3 | **-3.46 | **-6.42 | **-4.01 | **-7.03 |
| **DLQUK** | **-6.55 | **-8.90 | **-6.72 | **-8.95 | **-6.35 | **-8.40 | **-6.50 | **-8.44 |

**Note 1:** $\mu_0$ – constant; $\mu_1$ – trend; and **sd** – seasonal dummies. Critical values for columns (2), (3), (6) and (7): ** - significant at 1% = -3.43; * - significant at 5% = -2.86; Critical values for columns (4), (5), (8) and (9): ** - significant at 1% = -3.96; * - significant at 5% = -3.41.

**Note 2:** *column (2) and (3)* $\mu_0 \neq 0$: $\Delta y_t = \phi y_{t-1} + \Sigma^{p-1}_{j-1} \alpha^*_j \Delta y_{t-j} + \mu_0 + u_t$ ; *column (4) and (5)* $\mu_0 \neq 0, \mu_1 \neq 0$: $\Delta y_t = \phi y_{t-1} + \Sigma^{p-1}_{j-1} \alpha^*_j \Delta y_{t-j} + \mu_0 + \mu_1 t + u_t$ ; *column (6) and (7)* $\mu_0 \neq 0$, sd $\neq 0$: $\Delta y_t = \phi y_{t-1} + \Sigma^{p-1}_{j-1} \alpha^*_j \Delta y_{t-j} + \mu_0 + \pi_j s_i + u_t$ ; *column (8) and (9)* $\mu_0 \neq 0, \mu_1 \neq 0$, sd $\neq 0$: $\Delta y_t = \phi y_{t-1} + \Sigma^{p-1}_{j-1} \alpha^*_j \Delta y_{t-j} + \mu_0 + \mu_1 t + \pi_j s_i + u_t$.

Additionally, the Augmented Dickey Fuller (ADF) test procedure has been performed for log-levels and first differences of log-levels while using 1) constant, 2) constant and trend, 3) constant and seasonal dummies, and 4) constant, trend and seasonal dummies. Respective tests have been performed using one and zero lagged differences, (see Note 2 of Table 4.1). In the same way as plots, formal tests suggest that all three time series data need to be differenced once in order to render them into stationary time series. Specifically, the test value of 2.03 for LPUK in column (2) of Table 4.1 indicates that $H_0$ that there is unit root cannot be rejected at any level of significance. On the other side, the test value of -4.74 for DLPUK in column (2) of Table 4.1 indicates that $H_0$ that there is unit root can be rejected at 1 percent level of significance (l.s.). For LWUK in the test with zero lags the unit root hypothesis can be rejected when constant and trend (column 5), as well as when constant, trend and seasonal dummies (column 9) are fitted. Nonetheless, on the basis of overall evidence provided by the ADF test procedure it can be clearly argued that unlike log-levels the first differences of variables are stationary at 1 percent l.s.

## 5. VAR Estimation

In order to empirically investigate the pattern of causality between wages and prices in UK it is necessary to perform thorough econometric analysis. In addition to this, it is also required to subject all the models to a sequence of specification criteria and diagnostic tests in order to design statistically and theoretically robust models. This section presents the analysis of two VAR models, *first*, using log-levels ($VAR^L$) and *second*, using first differences of log-levels of variables ($VAR^D$). Even though, it is possible to estimate and present results of the unrestricted VAR models, as it will be done in the case of VECM model, considering space limitations and the fact that little information is lost by omitting them from analysis, only the parsimonious VAR models will be presented next. Quarterly seasonal dummies (S1, S2, and S3) and trend (t) have been fitted in both models. Concerning determination of optimal number of lags, searched up to 10 lags of levels, all four model selection criteria AIC, FPE, HQC and SC suggest fitting one lag for $VAR^L$ and zero lags for $VAR^D$, (see Table 5.1). However, for the purpose of avoiding potential under-fitting of the $VAR^D$ model one lag has been fitted. It is worth mentioning that while AIC frequently overestimates the number of lags, the SC provides the most consistent estimates. Furthermore, the Sequential Elimination of Regressors (SER) procedure employing SC has been utilized in both models in order to eliminate those regressors that lead to the largest reduction of information criteria, (Lütkepohl and Krätzig, 2004; Lütkepohl et al. 2006).

**Table 5.1.** *Determination of optimal number of lags for VAR models*

| Model | AIC | FPE | HQC | SC |
|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) |
| **$VAR^L$** | 1 | 1 | 1 | 1 |
| **$VAR^D$** | 8 | 0 | 0 | 0 |

***$VAR^L$*** - Considering that data sample includes observations from 1996:Q1 to 2007:Q4, i.e. T = 48, and by taking into account that one lag for endogenous and exogenous variables has been fitted in the model, then the total number of observations is T = 47. Complete results of this model have been presented in column (2) of Table 5.2. For example, the coefficient measuring impact of $LPUK_{t-1}$ on LWUK is interpreted as follows: if prices in the previous period increase by 1 percent, on average and ceteris paribus, the wages will increase by 0.41 percent. Additionally, three stars indicate that coefficient is significant at 1 percent l.s. The estimated productivity coefficient indicates statistically significant and positive effect on wages, specifically impact of $LQUK_{t-1}$ on LWUK is 0.56 and it is significant at 1 percent l.s., which effect is also in compliance with prior theoretical expectations. In contrast, $LQUK_{t-1}$ has no statistical impact on LPUK. From the coefficients of deterministic terms, those of seasonal dummies for LWUK are statistically insignificant, whereas trend coefficient is significant at 1 percent l.s. In contrary, coefficients of seasonal dummies for LPUK are significant at 1 percent, whereas trend coefficient is at 10 percent l.s. Thus, the evidence provided by $VAR^L$ model suggests that there is unilateral causal relationship running from prices to wages, and not vice versa.

**Table 5.2.** *Estimated coefficients of the VAR models*

| | $VAR^L$ | | | $VAR^D$ | | $VAR^{VECM}$ | |
|---|---|---|---|---|---|---|---|
| | LWUK | LPUK | | DLWUK | DLPUK | DLWUK | DLPUK |
| (1) | (2) | | (3) | (4) | | (5) | |
| $LWUK_{t-1}$ | - | - | $DLWUK_{t-1}$ | ***-0.56 | - | 0.26 | -0.04 |
| | | | | [-4.75] | | [0.00] | [0.00] |
| $LPUK_{t-1}$ | ***0.41 | ***1.00 | $DLPUK_{t-1}$ | **0.87 | - | 0.19 | 1.04 |
| | [4.76] | [5192.7] | | [2.12] | | [0.00] | [0.00] |
| $LWUK_{t-2}$ | n/a | n/a | $DLWUK_{t-2}$ | n/a | n/a | 0.55 | 0.00 |
| | | | | | | [0.00] | [0.00] |
| $LPUK_{t-2}$ | n/a | n/a | $DLPUK_{t-2}$ | n/a | n/a | 0.000 | 0.00 |
| | | | | | | [0.00] | [0.00] |
| LQUK | - | - | DLQUK | - | - | - | - |
| | | | | | | | |
| $LQUK_{t-1}$ | ***0.56 | - | $DLQUK_{t-1}$ | ***0.66 | - | n/a | n/a |
| | [6.56] | - | | [3.08] | - | | |
| $S_1$ | - | ***-0.01 | $S_1$ | - | ***-0.00 | 0.00 | -0.01 |
| | | [-7.45] | | | [-4.78] | [0.00] | [0.00] |
| $S_2$ | - | ***0.01 | $S_2$ | - | ***0.01 | 0.00 | 0.00 |
| | | [5.20] | | | [6.94] | [0.00] | [0.00] |
| $S_3$ | - | ***-0.01 | $S_3$ | - | ***-0.00 | 0.00 | -0.01 |
| | | [-5.38] | | | [-2.68] | [0.00] | [0.00] |
| Trend (t) | ***0.01 | *0.00 | Trend (t) | **0.00 | ***0.00 | 0.00 | 0.00 |
| | [56.79] | [1.71] | | [3.82] | [6.75] | [0.00] | [0.00] |

**Note 1:** *** - significant at 1 %; ** - significant at 5 %; * - significant at 10 %; n/a –respective coefficient has not been estimated in the model. Numbers in brackets represent t ratios.
**Note 2:** $\mathbf{VAR^{VECM}}$ coefficients in column (5) have been derived from the VECM.

***$VAR^D$*** - Now the sample includes only the observations from 1996:Q3 to 2007:Q4, as owing to one lagged difference fitted for both endogenous and exogenous variables in the model, as well as one degree of freedom lost with first difference transformation, then the total number of observations is T = 46. Complete results of this model have been presented in column (4) of Table 5.2. The coefficient which shows impact of prices ($DLPUK_{t-1}$) on wages (DLWUK) is interpreted as follows: if prices in the previous period increased by 1 percent, on average and ceteris paribus, the wages in the present period will increase by 0.87 percent. Additionally, two stars indicate that coefficient is significant at 5 percent l.s. In the same way as $VAR^L$, the estimated productivity coefficient in this model indicates positive and statistically significant effect on wages, specifically impact of $DLQUK_{t-1}$ on DLWUK is 0.66 and it is significant at 1 percent l.s. Once more, as in the previous model the $DLQUK_{t-1}$ has no statistically significant impact on DLPUK. From coefficients of deterministic terms, those of seasonal dummies for DLWUK are statistically not significant, whereas trend coefficient is significant at 1 percent l.s. On the other side, coefficients of seasonal dummies as well as trend coefficient for DLPUK are significant at 1 percent l.s. Hence, the evidence provided by $VAR^D$ model suggests that there is unilateral causal relation running from prices to wages, and not vice versa.

***Diagnostic tests*** - full details have been presented in appendix in Figure A5.1 and column (2) of Table A5.1 for *$VAR^L$*, respectively in Figure A5.2 and column (3) of Table A5.1 for *$VAR^D$*. First, the visual inspection of the plots of residuals, standardized residuals, correlation, autocorrelation and cross-correlation of residuals does not raise any concerns regarding the statistical adequacy of both models. Additionally, the formal diagnostic tests only reaffirm the previous assertion, thus on the basis of evidence from diagnostic tests it can be argued that these results are statistically robust. Specifically, Breusch–Godfrey test (Breusch, 1978; Godfrey, 1978) with 5 lags suggests no potential problems with residual autocorrelation, with test statistic being 23.09 and p-value 0.28 for $VAR^L$, and respectively 20.65 and 0.42 for $VAR^D$. Furthermore, all the tests for non-normality (Doornik and Hansen, 1994; Lütkepohl, 1993; Jarque-Bera, 1987), as well as ARCH-LM tests with 16 lags and Multivariate ARCH-LM tests with 5 lags raise no concerns regarding potential statistical issues in these models. Respective test statistics of all the mentioned diagnostic criteria are low and their p-values are sufficiently higher than the critical level of 0.10.

## 6. VECM Estimation

In case that two or more variables have a common stochastic trend, it may possible that there are linear combinations of them that are I(0). If that is the case then variables are cointegrated. In other words, a set of I(1) variables is called cointegrated if there is a linear combination of them that is I(0). Occasionally it is convenient to consider systems with both I(1) and I(0) variables. Thereby the concept of cointegration is extended by calling any linear combination that is I(0) a cointegration relation, although this terminology is not in the spirit of the original definition because it can happen that a linear combination of I(0) variables is called a cointegration relation. Although sometimes the VAR model may be suitable in accommodating variables with stochastic trends, it is not the most suitable type of model if interest centers on the cointegration relations, because they do not appear explicitly in those models, (Lütkhepohl and Krätzig, 2004). Thus, the VECM model that will be presented subsequently is a more convenient setup for analyzing variables with common stochastic trend. By the same token it may also be a more suitable model setup for analyzing the causal relationship between wages and prices in UK.

*Determination of cointegration rank - rk (Π)* – Complete results of cointegration tests have been presented in Table 6.1. Specifically, *Johansen Trace Test* and *Saikkonen and Lütkhepohl* test have been carefully utilized in examining the cointegration properties of LWUK and LPUK. Tests have been performed using quarterly seasonal dummy variables. Furthermore, as suggested by information criteria, tests have been performed with two and one lagged differences. In addition to this, the case with a) intercept, b) intercept plus trend, and c) orthogonal trend (the trend that is confined to some individual variables but is absent from the cointegration relations) have been performed for both types of cointegration test. When applying Johansen Test with two lagged differences the null hypothesis ($H_0$) that rk (Π) = 0, in favor of ($H_1$) that rk (Π) = 1, is rejected only in the case with intercept, with test statistic of 48.36 being significant at 1 percent l.s. When two lagged differences are used in the case when intercept plus trend and orthogonal trend are used the $H_0$ that rk(Π) = 0 cannot be rejected at any l.s. However, when the test is employed with one lagged difference the $H_0$ can be rejected in both cases when intercept and intercept plus trend are included in the testing procedure, specifically the values of test statistics of 82.18 and 40.61 respectively are significant at 1 percent l.s. In contrast the $H_0$ that rk(Π) = 0 cannot be rejected at any reasonable l.s. in the case of orthogonal trend.

Similarly the evidence from Saikkonen and Lütkhepohl test indicates that rk (Π) = 1. When two lagged differences are included in the test the $H_0$ that rk (Π) = 0 is rejected in favor of $H_1$ that rk (Π) = 1, only in the case when intercept is included with the value of test statistic 20.34 being significant at 1 percent l.s., and in the case when intercept plus trend are included with the value of test statistic 14.12 being significant at 10 percent l.s. Furthermore, when one lagged difference is included $H_0$ that rk (Π) = 0 is again rejected in the case when only intercept is included with the value of test statistic 57.11 being significant at 1 percent l.s., as well as in the case when intercept plus trend are included with the value of test statistics of 37.65 also being significant at 1 percent l.s. On the other hand, when orthogonal trend is included in the testing procedure of tests with two or one lagged differences, the $H_0$ that rk (Π) = 0 cannot be rejected in neither case. Finally, on the basis of overall results produced by cointegration tests it can be argued that there is sufficient evidence to proceed subsequent analysis with one cointegration relation included in the VECM model, i.e. rk (Π) = 1.

**Table 6.1.** *Tests for the rank of cointegration*

| **Test** | **Ld** | **Intercept** ($\mu_0 \neq 0$ $\mu_1 = 0$) | | **Intercept + trend** ($\mu_0 \neq 0$ $\mu_1 \neq 0$) | | **Orthogonal trend** |
|---|---|---|---|---|---|---|
| | rk (Π) | rk (Π) = 0 | rk (Π) = 1 | rk (Π) = 0 | rk (Π) = 1 | rk (Π) = 0 |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| **Johansen** | 2 | ***48.36 | 2.65 | 19.52 | 4.50 | 8.68 |
| | | (0.00) | (0.65) | (0.26) | (0.67) | (0.40) |
| | 1 | ***82.18 | 3.64 | ***40.61 | 3.32 | 9.35 |
| | | (0.00) | (0.48) | (0.00) | (0.83) | (0.34) |
| **Saikkonnen & Lutkhepol** | 2 | ***20.34 | 2.59 | *14.12 | 0.51 | 3.54 |
| | | (0.00) | (0.13) | (0.09) | (0.92) | (0.54) |
| | 1 | ***57.11 | 2.29 | ***37.65 | 0.47 | 6.57 |
| | | (0.00) | (0.15) | (0.00) | (0.93) | (0.19) |

**Note 1**: $H_0$: rk (Π) = 0 *vs*. $H_1$: rk (Π) = 1, and $H_1$: rk (Π) = 1 *vs*. $H_2$: rk (Π) = 2.

**Note 2**: *** - significant at 1 %; ** - significant at 5 %; * - significant at 10 %. Numbers in brackets represent p-values. *ld* – lagged differences.

**Note 3**: Types of cointegration tests: **a) $\mu_0 \neq 0$, $\mu_1 = 0$**: Johansen - $\Delta y_t = \Pi(y_{t-1} - \mu_0) + \sum_{j=1}^{p-1} \Gamma_j \Delta y_{t-j} + u_t$; S&L - $\Delta y_t = \Pi^* \begin{bmatrix} y_{t-1} \\ 1 \end{bmatrix} + \sum_{j=1}^{p-1} \Gamma_j \Delta y_{t-j} + u_t$; **b) $\mu_0 \neq 0$, $\mu_1 = 0$:** Johansen - $\Delta y_t - \mu_1 = \Pi(y_{t-1} - \mu_0 -$ *μ1(t−1)+j=1p−1ΓjΔyt−j−μ1+ut*, S&L - *Δyt=v+Π+yt−1t−1+j=1p−1ΓjΔyt−j+ut*, **c) orthogonal Trend**: Johansen - $\Delta y_t - \mu_1 = \Pi(y_{t-1} - \mu_0) + \sum_{j=1}^{p-1} \Gamma_j (\Delta y_{t-j} - \mu_1) + u_t$ ; S&L $\Delta y_t = v_0 + \Pi y_{t-1} + \sum_{j=1}^{p-1} \Gamma_j \Delta y_{t-j} + u_t$, (Lütkhepohl and Krätzig, 2004).

*Number of lagged differences (ld)* – prior to running the VECM regression it is necessary to determine the number of *ld* by utilizing relevant information criteria. The test results on the suggested number of *ld* have been presented in Table 6.2, and on the basis of obtained evidence it can be argued that the suggested number of *ld* for unrestricted model ($VECM^U$) does not differ from the one suggested for restricted model ($VECM^R$). In principle, whereas AIC overestimates the number of lagged differences the SC provides the most consistent estimates. In both cases AIC, FPE and HQC suggest 10 lagged differences whereas SC suggests zero lagged differences. Nonetheless, for the purpose of avoiding potential under-fitting of the VECM model one lagged difference has been fitted for exogenous and endogenous variables. This is so, as in some cases despite the fact that information criteria may suggest fitting zero lagged differences one or more coefficients of lagged variables may still indicate that there is a statistically significant effect after the regression has been run. In this model LWUK and LPUK have been set as endogenous variables, whereas LQUK has been set as an exogenous variable. Quarterly seasonal dummies (S1, S2, and S3) and trend (t) have been fitted in the model. Intercept is included only in the $VECM^U$ and it is excluded from the $VECM^R$. As a matter of fact, it is worth mentioning that intercept term is explicitly absent in the mathematical model, hence the $VECM^R$ may also be a practical tool to test the validity of hypothesis on whether the intercept term is present or not in the wage-price relationship.

**Table 6.2.** *Determination of optimal number of lagged differences for VECM models*

| Model | AIC | FPE | HQC | SC |
|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) |
| **$VECM^U$** | 10 | 10 | 10 | 0 |
| **$VECM^R$** | 10 | 10 | 10 | 0 |

*Interpretation of estimated coefficients β of cointegration matrix* - It has to be noted that the first coefficient in the cointegrating relation $\beta_1$ has been normalized to 1 by JMulTi software, i.e. $\beta_1 = 1$. With this normalization, one should also verify whether the estimated cointegrating relation $\beta_2$ is close to what one would expect on the basis of prior considerations. In general, without normalizing the coefficient associated with the first variable, $LWUK_{t-1}$ in this case, such a result is unlikely because the Reduced Rank (RR) estimation procedure imposes statistical uniqueness constraints on the estimated cointegration parameters, which do not take any prior economic considerations into account. Taking into account the fact that the first coefficient of cointegration vector is normalized, one can then use the asymptotic distribution of the second coefficient to test whether the expected value of the cointegration relation $\beta_2$ is as expected.

In general, the *loading coefficients α* are also to some extent arbitrary because they are determined by normalization of cointegrating vectors, however their t-ratios can be interpreted in the usual way as being “conditional on the estimated cointegration coefficients.” In other words, they can be used for assessing whether the cointegration relations resulting from our normalization enter a specific equation significantly. Because they are in fact asymptotically normal, using them with critical values from a standard normal distribution can be justified in the usual way. Hence, the systems are evaluated on whether the cointegration relation is an important variable in both equations, (i.e. whether the estimated loading coefficients have absolute t-ratios greater than 2). The estimators of the parameters associated with lagged differences of the variables (short-run parameters) may be interpreted in the usual way. Their t-ratios are asymptotically normal under our assumptions. The same is not necessarily true for the parameters associated with deterministic terms. Their t-ratios are just given for completeness (Lütkhepohl and Krätzig, 2004, 2005).

**Table 6.3.** *VECM Coefficients with Simple Two Step (S2S) Procedure*

| **Model** | **VECM^U^** | | **VECM^R^** | |
|---|---|---|---|---|
| (1) | (2) | | (3) | |
| **$\alpha_1$** | ***-0.75 | | ***-0.19 | |
| | [-3.48] | | [-5.32] | |
| **$\alpha_2$** | -0.05 | | ***-0.04 | |
| | [-1.24] | | [-5.50] | |
| **$\beta_1$** | 1.00 | | 1.00 | |
| | [0.00] | | [0.00] | |
| **$\beta_2$** | *0.522 | | ***-1.002 | |
| | [1.64] | | [-315.92] | |
| (1) | (2a) | (2a) | (3a) | (3b) |
| | **DLWUK** | **DLPUK** | **DLWUK** | **DLPUK** |
| **$DLWUK_{t-1}$** | -0.23 | -0.01 | ***-0.55 | - |
| | [-1.46] | [-0.18] | [-5.27] | |
| **$DLPUK_{t-1}$** | 0.36 | -0.23 | - | - |
| | [0.43] | [-1.57] | | |
| **LQUK** | 0.17 | *-0.04 | - | - |
| | [1.31] | [-1.67] | | |
| **Constant ($\mu_0$)** | ***4.28 | *0.49 | n/a | n/a |
| | [2.97] | [1.94] | | |
| **$S_1$** | -0.01 | ***-0.01 | - | ***-0.007 |
| | [-0.80] | [-5.04] | | [-8.02] |
| **$S_2$** | -0.01 | ***0.00 | - | ***0.004 |
| | [-0.97] | [4.35] | | [5.36] |
| **$S_3$** | 0.00 | 0.00 | - | ***-0.005 |
| | [-0.40] | [-1.61] | | [-5.83] |
| **Trend (t)** | ***0.01 | *0.00 | ***0.001 | ***0.000 |
| | [3.26] | [1.70] | [7.59] | [8.09] |

**Note 1**: *** - significant at 1 %; ** - significant at 5 %; * - significant at 10 %. Numbers in brackets show t ratios.

Even though the sample includes data from 1996:Q1 to 2007:Q4, i.e. T = 48, only T = 46 observations have been used in the VECM models, as one lagged difference has been fitted in the models and also one observation has been lost due to first difference transformation. Full results of estimated VECM models have been presented in Table 6.3, respectively $VECM^U$ in column (2), and $VECM^R$ in column (3), both using the Two Stage (S2S) estimation procedure, i.e. Johansen procedure in the first stage and Feasible Generalized Least Squares (FGLS) procedure in the second stage. However, it is worth emphasizing that Sequential Elimination of Regressors (SER) procedure using SC has been employed in the restricted model in order to eliminate those regressors that lead to the largest reduction of the respective information criteria, (Lütkhepohl and Krätzig, 2004, 2005). Hence, all the coefficients with $t$ ratios lower than two have been eliminated or restricted to zero in the second stage.

**$VECM^U$** complete results have been presented in column (2) of Table 6.3. On the basis of estimated loading coefficients from this model it can be argued that cointegration relation resulting from normalization of cointegration vector enters significantly only in the first equation, i.e. wage equation, with estimated coefficient $\alpha_1$ = -0.75 and test statistic of -3.48 being significant at 1 percent l.s. In contrast, it does not enter in statistically significant way in the second equation with $\alpha_1$ = -0.05 and test statistic of 1.24 is statistically insignificant. Now by selecting $LWUK_t$ as the first variable in the model means that the coefficient of this variable in the cointegration relation, i.e. $\beta_1$, will be normalized to 1 in the maximum likelihood estimation procedure. This normalization is tricky if LWUK is not actually present in the cointegration relation. The value of the second cointegration coefficient $\beta_2$ is 0.52, however the low value of the test statistic indicates that there is weak evidence of cointegration relationship between $LWUK_t$ and $LPUK_t$. Consequently, the model can be presented in the simple form as,

$$LWUKt = -\ 0.52\ LPUK_t + ec_t^{FGLS} \qquad (6.1)$$
$$[1.64]$$

where numbers in brackets represent *t* ratios. Considering that logs of variables have been used, the relation in (6.1) expresses the elasticity of wages on prices, i.e. the coefficient of 0.52 is estimated wage elasticity. Accordingly, if the log prices increases by 1%, it is expected that the log of wages would decrease by 0.52 percent, which is in contradiction with *a priori* theoretical expectations. In other words, a 1 percent increase in the log prices would induce a 0.52 percent decrease in the log of wages. This coefficient is statistically significant only at 10 percent l.s.

On the other side, none of the coefficients associated with lagged variables are statistically significant at any reasonable l.s. Furthermore, the estimated productivity coefficient LQUK has no statistically significant impact on wages, i.e. LWUK, whereas it indicates a small though negative effect on prices, specifically its impact on LPUK is 0.04 and it is significant at 10 percent l.s. From deterministic terms, coefficients of seasonal dummies for DLWUK are statistically not significant, whereas coefficient of trend is significant at 1 percent l.s. On the other side, the first two coefficients of seasonal dummies for DLPUK are significant at 1 percent and the third is not significant, whereas coefficient of trend is significant at 10 percent l.s. Constant term is statistically significant at 1 percent in the first equation, whereas it is 10 percent in the second equation. Nonetheless, one has to bear in mind that constant term is not present in the mathematical relationship between wages, prices and productivity. Thus, the restricted model will impose zero restriction on the constant as well as all other coefficients with low value of test statistic in order to design a more parsimonious model.

**$VECM^R$** full results have been presented in column (3) of Table 6.3. One the basis of estimated loading coefficients from this model it can be argued that cointegration relation resulting from normalization of cointegration vector enters significantly in both equations. The loading coefficient $\alpha_1$ = -0.19 for the wage equation has a test statistic of -5.32, and the other coefficient $\alpha_2$ = -0.04 for the price equation has a test statistic of -5.50. Thus unlike $VECM^U$, both loading coefficients in this model are significant at 1 percent l.s. Again by selecting $LWUK_t$ as first variable in the model, it means that the coefficient of this variable in the cointegration relation will be normalized to 1 in the maximum likelihood estimation procedure. The high value of test statistic of the second coefficient, $\beta_2$, indicates that there is sufficient evidence of a strong cointegration relationship between $LWUK_t$ and $LPUK_t$. Consequently, the model can be presented in the simple form as,

$$LWUKt = 1.002\ LPUK_t + ec_t^{FGLS} \qquad (6.2)$$
$$[-315.92]$$

where the numbers in brackets represent *t* ratios. Taking into account that logs of variables have been used, the relation in (6.3) expresses the elasticity of wages on prices, hence the coefficient of 1.00 is the estimated wage elasticity. Accordingly, if the log of prices increases by 1 percent it is expected that the log of wages would increase by 1 percent. In other words, a 1 percent increase in the log of prices would induce a 1 percent increase in the log of wages. Importantly, this coefficient is statistically significant at 1 percent l.s.

When the coefficients associated with lagged variables are analyzed, it results that only the coefficient which estimates impact of $DLWUK_{(t-1)}$ on DLWUK, is statistically significant at 1 percent l.s. In contrast, all other coefficients have been restricted to zero given that their t-ratios had low values, hence through the use of SER procedure have been eliminated in the second stage of VECM estimation when FGLS procedure was used. Furthermore, the estimated productivity coefficient of LQUK indicates no statistically significant impact, neither on LWUK nor on LPUK. From coefficients of deterministic terms, those of seasonal dummies for LWUK are statistically insignificant, whereas trend coefficient is significant at 1 percent l.s. At the same time, all coefficients of seasonal dummies for LPUK as well as trend coefficient are significant at 1 percent l.s. As previously explained, the constant term has been excluded from the model.

***Diagnostic tests*** - full details have been presented in appendix in Figure A6.1 and column (4) of Table A5.1 for $VECM^U$, respectively in Figure A6.2 and column (5) of Table A5.1 for $VECM^R$. In summary, the visual inspection of the plots of residuals, standardized residuals, correlation, autocorrelation and cross-correlation of residuals raises no concerns on the statistical adequacy of either model. Additionally, the formal diagnostic tests only reaffirm the previous assertion, thus on the basis of evidence from diagnostic tests it can be argued that these results are statistically robust. Specifically, Breusch-Godfrey test (see Breusch, 1978; Godfrey, 1978) with 5 lags suggests no potential problems with residual autocorrelation, with test statistic being 16.71 and p-value being 0.67 for $VECM^U$, and respectively 18.93 and 0.53 for $VECM^R$. Furthermore, all the tests for non-normality (Doornik and Hansen, 1994; Lütkepohl, 1993; Jarque-Bera, 1987), as well as ARCH-LM tests with 16 lags and Multivariate ARCH-LM tests with 5 lags raise no concerns regarding potential statistical issues in these models. Respective test statistics are low and their p-values are sufficiently higher than the critical level of 0.10.

**Comparing $VECM^U$ and $VECM^R$** - Important information in evaluating the robustness of this model is VECM model statistics, (see Lütkhepohl and Krätzig 2004). The value of LR-test is 3.57 and p-value is 0.89, hence on the basis of this statistic it can be argued that no information is lost if restrictions are imposed on the VECM model by SER procedure, or one may not reject the hypothesis that the restricted model ($H_0$) is a better representation of DGP than the unrestricted model ($H_1$). Next the values of cointegration coefficients of each model are compared with the value that one would expect on the basis of prior theoretical considerations. In a simple theoretical model, the rational expectations approach assumes that people use all relevant information in forming expectations of economic variables. For example changes in the price level as a result of increase in money stock, leave output and employment unchanged. Money and wages will rise, but since the real wage is unchanged, neither the quantity of labor supply nor that demand will change, (see for example Muth, 1961; Sargent and Wallace, 1976). Hence, provided that assumption on rational expectations holds true, it is expected that the wage elasticity is going to have the value of one.

Next, one can use the asymptotic distribution of cointegration coefficients, $\beta_2$, of each model to test the hypotheses ($H_0$) that the values of estimated elasticity coefficients from equations (6.1) and (6.2) are -1, as theoretically expected, or that they are statistically different from -1. Hence, a t test can be conducted as follows:

$H_0: \beta_2 = -1$, versus $H_A: \beta_2 \neq -1$ (6.3)

Specifically, test statistic is calculated using formula $t = (\hat{\beta}_1 + 1) / (se)$. The value of test statistic for $VECM^U$ is t = (0.522 + 1) / 0.318 = 4.79, and for $VECM^R$ t = (-1.002 + 1) / 0.003 = - 0.67, (see Lütkhepohl and Krätzig, 2004). In the case of $VECM^U$ not only the zero hypotheses, $H_0$, is rejected, but the coefficient $\beta_2$ also has incorrect sign and is in contradiction with a priori theoretical assumptions. In contrast, zero hypotheses for the cointegration coefficient $\beta_2$ of $VECM^R$ cannot be rejected at any reasonable level of significance. In the light of this, it can be argued that the simple t test indicates that the value of coefficient $\beta_2$ is not different from -1, as theoretically expected. Hence, this is an additional argument in support of hypothesis that $VECM^R$ has a better representation of DGP than $VECM^U$. In the end, not only statistically, but most importantly in terms of economic accuracy it better describes the relationship between wages and prices as well.

## 7. Conclusion

As it has been noted in the process of literature review on the causal relationship between wages and prices there are two opposing opinions with regards to the flow of causality. In addition to this, it is evident that various studies have used different sample ranges, various datasets, and have consequently obtained different conclusions on the nature of relationship. Considering all the facts, it can be argued that it is very difficult to reject the Hess and Schweitzer (2000) hypothesis that respective conclusions on the causal relationship ultimately depend on a number of elements such as sample length, the number of explanatory variables used (including the number of lags of each variable) and in particular the use of specific measure of prices (see also Emery and Chang, 1996). Equally, it is important to emphasize Palley (1999) argument that causal relationship may change with economics cycles.

The evidence provided by both VAR models, log-levels and first differences, suggests that in the case of UK there is unilateral causal relationship running from prices to wages, and not vice versa. Regardless of the fact that diagnostic tests indicate no statistical issues, the VAR modeling procedure is inadequate in that it is incapable in explicitly estimating cointegrating relationships. Clearly, the cointegration tests, Johansen Trace Test as well as Saikkonen and Lütkepohl test, have suggested that there is sufficient evidence in favor of analyzing the wage and price relationship with one cointegration relation included in the VECM model. The VECM models have been estimated using the S2S procedure, with *Johansen procedure* used in the first stage and FGLS in the second stage, while SER has been utilized only in the restricted model. Although the cointegration relationship enters significantly only in the wage equation in the unrestricted model, it enters significantly in both wage and price equations in the restricted VECM model. Furthermore, VECM model statistics suggests that no information is lost when restrictions are imposed on the VECM model. The strongest evidence against the unrestricted model is the fact that the estimated cointegration coefficient is not only significantly different from its expected value but it has incorrect sign too. In contrast, it is very obvious on the basis of prior theoretical expectations that the value of the estimated cointegration coefficient of restricted model is almost identical to the expected value.

## References

Andersson, J. (2005). Testing for Granger Causality in the presence of measurement errors. *Economics Bulletin.* Vol. 3. No. 47. pp. 1-13.

Ashley, R., Granger, C.W.J. and Schmalensee, (1980). Advertising and Aggregate Consumption: An Analysis of Causality. *Econometrica.* Vol. 48. No. 5. July. pp. 1149-1167.

Breusch, T.S. (1978). Testing for Autocorrelation in Dynamic Linear Models. *Australian Economic Papers.* 17. pp. 334-355.

Davidson, R. and MacKinnon, J. (1993). *Estimation and Inference in Econometrics.* Oxford University Press. London.

DeGrauwe, P. (2003). *Economics of Monetary Union.* Fifth edition. Oxford University Press.

Dickey, D.A. and Fuller, W.A. (1979). Estimators for autoregressive time series with a unit root. *Journal of the American Statistical Association.* 74. pp. 427-431.

Doornik, J.A. and Hansen, H. (1994). A practical test of multivariate normality. Unpublished paper. Nuffield College.

Doraszelski, U. and Jaumandreu, J. (2013). R&D and Productivity: Estimating Endogenous Productivity. *Review of Economic Studies.* 80. pp. 1338-1383.

Emery, K.M. and Chang, C.P. (1996). Do Wages Help Predict Inflation?. Federal Reserve Bank of Dallas. Economic Review of the First Quarter 1996.

Fuller, W.A. (1976). *Introduction to Statistical Time Series.* John Wiley & Sons. New York.

Garcia, C.J. and Restrepo, J.G. (2001). Price and wage inflation in Chile. *BIS Papers*. No. 8 (part 5). November 2001.

Gilbert, C.L. (2004). Economic Causality. Paper prepared for the 2004 Annual Causality. Metaphysics and Methods Conference. LSE. London. 15-17 June.

Goretti, M. (2008). Wage-Price Setting in New EU Member States. *IMF Working Paper*. WP/08/243.

Godfrey, L.G. (1978). Testing Against General Autoregressive and Moving Average Error Models when the Regressors Include Lagged Dependent Variables. *Econometrica.* 46. pp. 1293-1301.

Granger, C.W.J. (1969). Investigating Causal Relations by Econometric Models and Cross-spectral Methods. *Econometrica.* Vol. 37. No. 3. August. pp. 424-438.

Haavlemo, T. (1994). The probability Approach in Econometrics. *Econometrica.* 12. Issue Supplement. July. iii-vi. pp. 1-115.

Hess, G.D. and Schweitzer, M.E. (2000). Does Wage inflation cause price Inflation?. Federal Reserve Bank of Cleveland. *Policy Discussion Paper*. No. 10. April.

Hume, D. (1739). *A Treatise of Human Nature.* Reprinted from the Original Edition in three volumes and edited. With an analytical index, By L.A. Selby-Bigge. M.A. Oxford. Clarendon Press.

Jarque, C.M. and Berra, A.K. (1987). A test for normality of observation and regression residuals. *International Statistical Review.* 55. pp. 163-172.

Jonsson, M. and Palmqwist, S. (2004). Do Higher Wages Cause Inflation?. Sveriges Riskbank. *Working Paper Series.* April.

Jung, C. and Seldon, B. (1995). The Macroeconomic Relation between Advertising and Consumption. *Southern Economic Journal.* Vol. 61.

Lemos, S. (2004). The Effect of the Minimum Wage on Prices. University of Leicester. *Working Paper*. No. 04/7. March.

LeRoy, S.F. (2004). Causality in Economics, Centre for Philosophy of Natural and Social Science Causality: Metaphysics and Methods. Technical Report 20/04.

Lütkepohl, H. (1993). Testing for causation between two variables in higher dimensional VAR models. In H. Schneeweiss and K.F. Zimmermann (eds.). *Studies in Applied Econometrics.* Physica-Verlag. Heidelberg. p. 7591.

Lütkhepohl, H. and Krätzig, M. (2004). *Applied Time Series Econometrics.* Cambridge University Press. October.

Lütkhepohl, H. and Krätzig, M. (2005). VECM Analysis in JMulTi. www.jmulti.de

Lütkhepohl, H., Krätzig, M. and Boreiko, D. (2006). VAR Analysis in JMulTi, www.jmulti.de

Lütkhepohl, H. and Krätzig, M. (2006). Initial Analysis in JMulTi. www.jmulti.de

Moschos D. (1983). Aggregate Price Responses to Wage and Productivity Changes: Evidence from the US. *Empirical Economics.* Vol. 8. pp. 169-75.

Muth, J. (1961). Rational Expectations and the Theory of Price Movements. *Econometrica.* Vol. 29. No. 3. July.

Ng, S. and Perron, P. (1995). Unit root tests in ARMA models with data-dependent methods for the selection of the truncation lag. *Journal of the American Statistical Association.* 90. pp. 268-281.

Palley, T.I. (1999). The U.S. Inflation Process: Does Nominal Wage Inflation cause Price Inflation, Vice-versa, or Neither?. Presented at the annual ASSA/URPE Conference held in New York. NY. 2-3 January.

Pu, C., Flaschel, P. and Chihying, H. (2006). A Causal Analysis of the Wage-Price Spiral. *Working Paper*. March 14.

Sargent, T.J. and Wallace, N. (1976). Rational Expectations and Theory of Economic Policy. *Journal of Monetary Economics.* 2. pp. 169-183. North-Holland Publishing Company.

Sims, C. (1972). Money, Income and Causality. *The American Economic Review.* Vol. 62. No. 4. September. pp. 540-552.

Sims, C. (1999). Granger Causality. Econ. 513. *Time Series Econometrics.* Fall.

Smolny, W. (2000). Sources of productivity growth: an empirical analysis with German sectoral data. *Applied Economics.* 32. pp. 305-314.

Solow, Robert M. (1959). A Contribution to the Theory of Economic Growth. *The Quarterly Journal of Economics.* Vol. 70. No. 1. February. pp. 65-94.

Stiroh, K.J. (2001). What Drives Productivity Growth?. FRBNY Economic Policy Review. March. pp. 37-59.

Strauss, J. and Wohar, M.E. (2004). The Linkage between prices, wages and productivity: a panel study of manufacturing industries. *Southern Economic Journal.* April.

## Appendix

**Table A4.1.** *Description of the price, wage and productivity variables*

| **Variable** | **Description of variables** |
|---|---|
| (1) | (2) |
| c *or* $\mu_0$ | Constant / Intercept |
| t *or* $\mu_1$ | Trend |
| $s_0$, $s_1$, $s_2$, $s_3$, | Seasonal dummy variables for quarters (I,II, III, IV) |
| WUK | Wages |
| LWUK | Log of WUK |
| DLWUK | First Difference of the log of WUK |
| PUK | Price Index |
| LPUK | Log of PUK |
| DLPUK | First Difference of the log of PUK |
| QUK | Productivity |
| LQUK | Log of QUK |
| DLQUK | First Difference of the log of QUK |

**Table A4.2.** *Augmented Dickey-Fuller (ADF) unit root test – number of lagged differences suggested by a) AIK, b) FPE, c) HQC, and SC, (Lütkhepohl and Krätzig, 2004).*

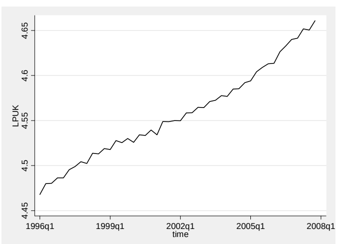
| **Variable** | $\mu_0$ | | | | $\mu_0 + \mu_1$ | | | | $\mu_0$ + sd | | | | $\mu_0 + \mu_1$ + sd | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) | (2) | | | | (3) | | | | (4) | | | | (5) | | | |
| | (a) | (b) | (c) | (d) | (a) | (b) | (c) | (d) | (a) | (b) | (c) | (d) | (a) | (b) | (c) | (d) |
| **LPUK** | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 |
| **LWUK** | 6 | 6 | 1 | 1 | 0 | 0 | 0 | 0 | 6 | 6 | 1 | 1 | 1 | 1 | 0 | 0 |
| **LQUK** | 8 | 8 | 1 | 0 | 10 | 10 | 10 | 0 | 8 | 8 | 1 | 0 | 10 | 10 | 10 | 0 |
| **DLPUK** | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 5 | 5 | 0 | 0 | 0 | 0 | 0 | 0 |
| **DLWUK** | 0 | 0 | 0 | 0 | 5 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 5 | 0 | 0 |
| **DLQUK** | 7 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 7 | 7 | 0 | 0 | 7 | 7 | 0 | 0 |

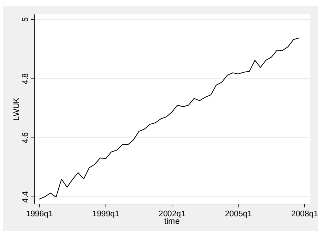
***Note 1:*** *column (2)* $\mu_0 \neq 0$: $\Delta y_t = \phi y_{t-1} + \Sigma^{p-1}{}_{j-1}\, \alpha^*{}_j\, \Delta y_{t-j} + \mu_0 + u_t$ ; *column (3)* $\mu_0 \neq 0$, $\mu_1 \neq 0$: $\Delta y_t = \phi y_{t-1} + \Sigma^{p-1}{}_{j-1}\, \alpha^*{}_j\, \Delta y_{t-j} + \mu_0 + \mu_1 t + u_t$ ; *column (3)* $\mu_0 \neq 0$, sd $\neq 0$: $\Delta y_t = \phi y_{t-1} + \Sigma^{p-1}{}_{j-1}\, \alpha^*{}_j\, \Delta y_{t-j} + \mu_0 + \pi_j s_i + u_t$ ; column (5) $\mu_0 \neq 0$, $\mu_1 \neq 0$, sd $\neq 0$: $\Delta y_t = \phi y_{t-1} + \Sigma^{p-1}{}_{j-1}\, \alpha^*{}_j\, \Delta y_{t-j} + \mu_0 + \mu_1 t + \pi_j s_i + u_t$.

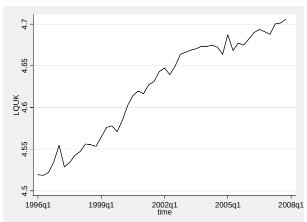
**Figure A4.1.** *Plots of wage, price and productivity variables: a) log-levels and b) first difference of log-level.*

Price Wage Productivity

(a)



(b)

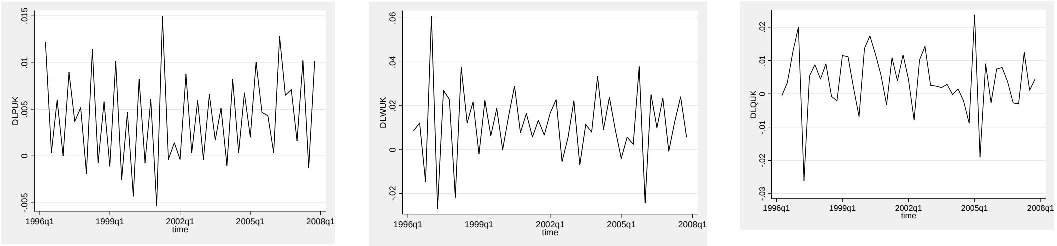
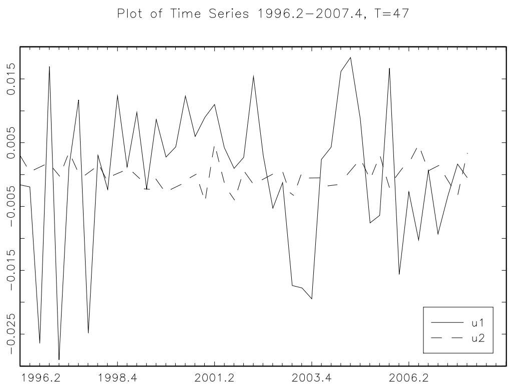
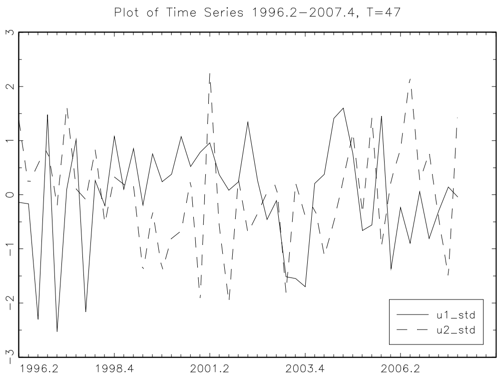



**Figure A5.1.** *VAR Levels Model (VAR$^L$) - Graphical Diagnostic Checks*

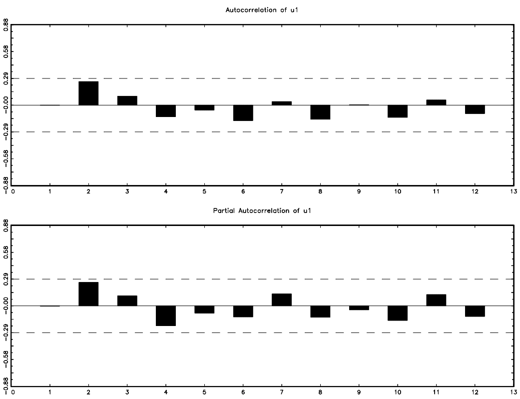
Residuals $u_{1t}$ and $u_{2t}$



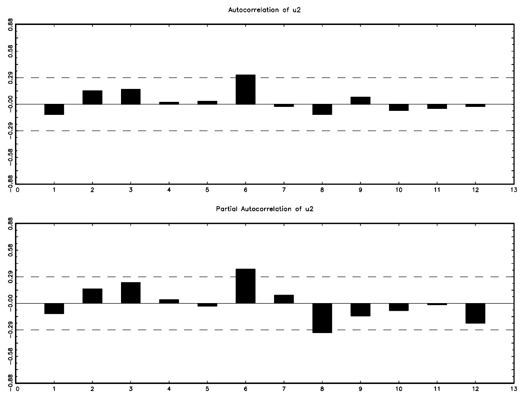

Standardized residuals $u_{1t}$ and $u_{2t}$




AC and PAC of $u_{1t}$




AC and PAC of $u_{2t}$



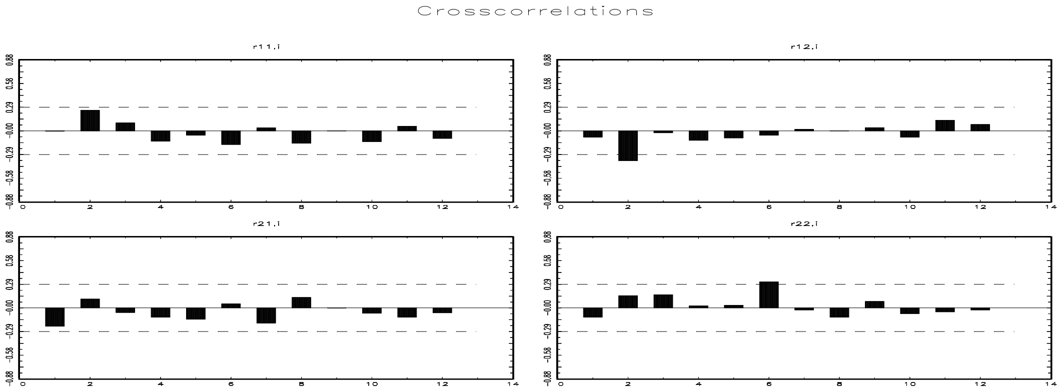
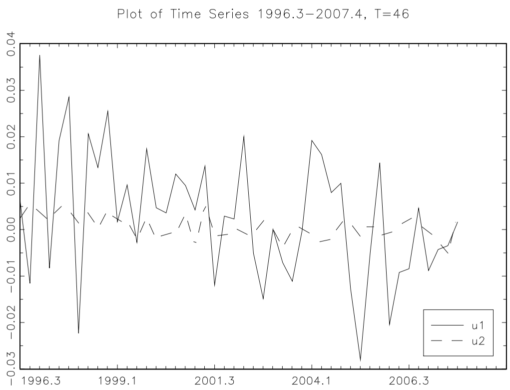
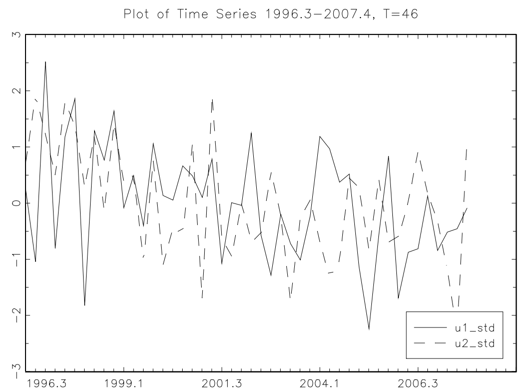



**Figure A5.2.** *VAR First Differences Model ($VAR^D$) - Graphical Diagnostic Checks*

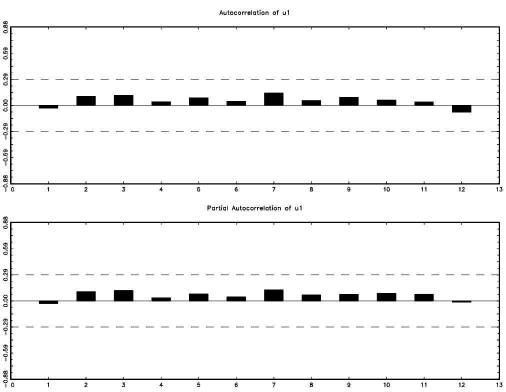
Residuals $u_{1t}$ and $u_{2t}$



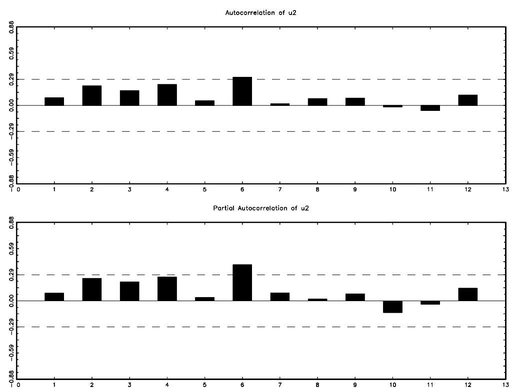

Standardized residuals $u_{1t}$ and $u_{2t}$




AC and PAC of $u_{1t}$




AC and PAC of $u_{2t}$



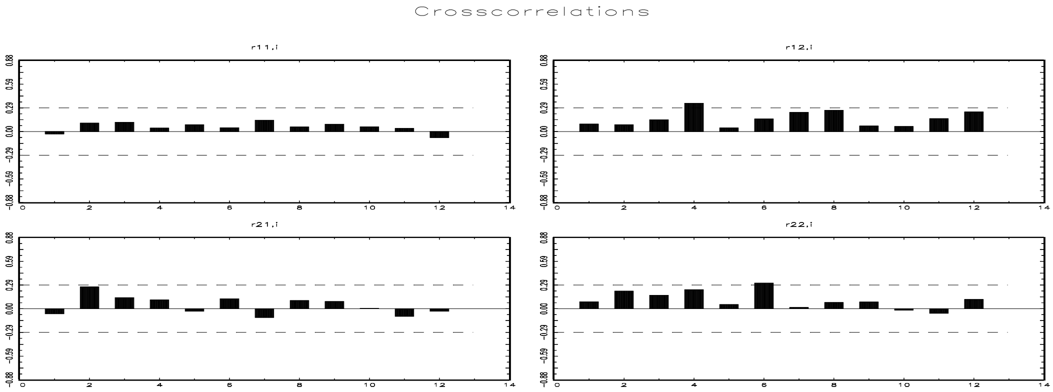


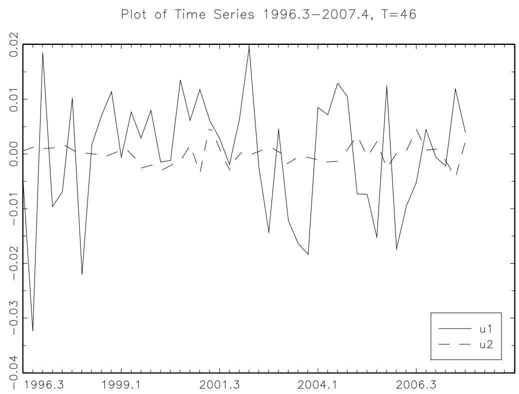

**Table A5.1.** *Diagnostic Tests for the VAR and VECM models*

| Model | $VAR^L$ | $VAR^D$ | $VECM^U$ | $VECM^R$ |
|---|---|---|---|---|
| **(1)** | **(2)** | **(3)** | **(4)** | **(5)** |
| LM-Type Test for autocorrelation with 5 lags | 23.09 | 20.65 | 16.71 | 18.93 |
| | (0.28) | (0.42) | (0.67) | (0.53) |
| **TESTS FOR NONNORMALITY** | | | | |
| **Doornik & Hansen (1994)** | 3.99 | 0.78 | 4.60 | 1.66 |
| | (0.41) | (0.94) | (0.33) | (0.80) |
| Skewness | 3.93 | 0.16 | 4.00 | 0.56 |
| | (0.14) | (0.92) | (0.14) | (0.76) |
| Kurtosis | 0.06 | 0.61 | 0.60 | 1.10 |
| | (0.97) | (0.74) | (0.74) | (0.58) |
| **Lütkepohl (1993)** | 3.97 | 0.79 | 4.57 | 1.06 |
| | (0.41) | (0.94) | (0.33) | (0.90) |
| Skewness | 3.91 | 0.25 | 3.99 | 0.43 |
| | (0.14) | (0.88) | (0.14) | (0.80) |
| Kurtosis | 0.06 | 0.53 | 0.58 | 0.63 |
| | (0.97) | (0.77) | (0.75) | (0.73) |
| **Jarque-Berra Test** | | | | |
| $u_1$ | 3.82 | 0.24 | 3.16 | 0.86 |
| | (0.15) | (0.89) | (0.21) | (0.65) |
| $u_2$ | 0.16 | 0.65 | 0.69 | 0.24 |
| | (0.92) | (0.72) | (0.71) | (0.89) |
| **ARCH-LM TEST** with 16 lags | | | | |
| $u_1$ | 16.42 | 10.83 | 9.38 | 8.62 |
| | (0.42) | (0.82) | (0.90) | (0.93) |
| $u_2$ | 12.35 | 8.43 | 8.51) | 16.42 |
| | (0.72) | (0.94) | (0.93) | (0.42) |
| **MULTIVARIATE ARCH**-LM TEST with 5 lags | | | | |
| VARCH LM test statistic | 37.50 | 46.67 | 43.64 | 47.06 |
| | (0.78) | (0.40) | (0.53) | (0.39) |

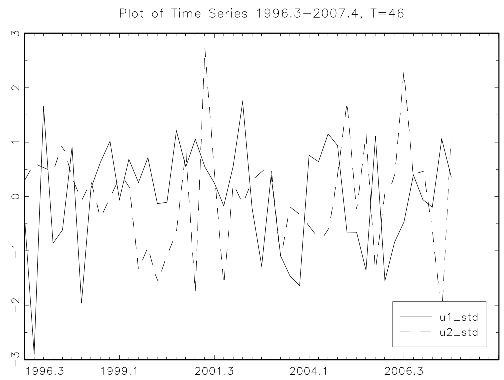
**Note 1**: The numbers in brackets represent p-values.

**Figure A6.1.** *VECM Unrestricted Model (VECM$^U$) - Graphical Diagnostic Checks*

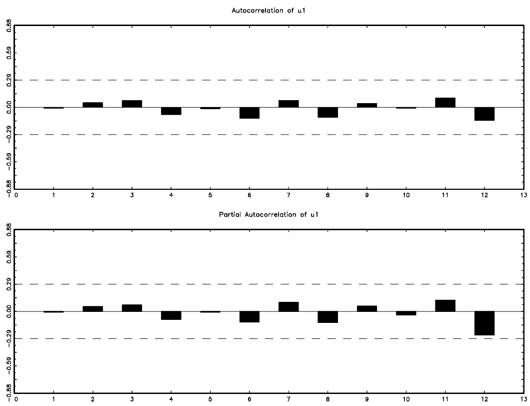
Residuals $u_{1t}$ and $u_{2t}$



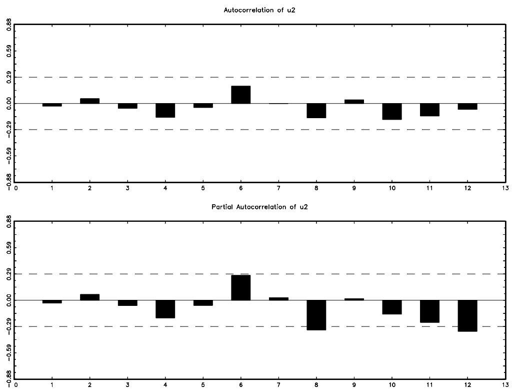

Standardized residuals $u_{1t}$ and $u_{2t}$




AC and PAC of $u_{1t}$




AC and PAC of $u_{2t}$



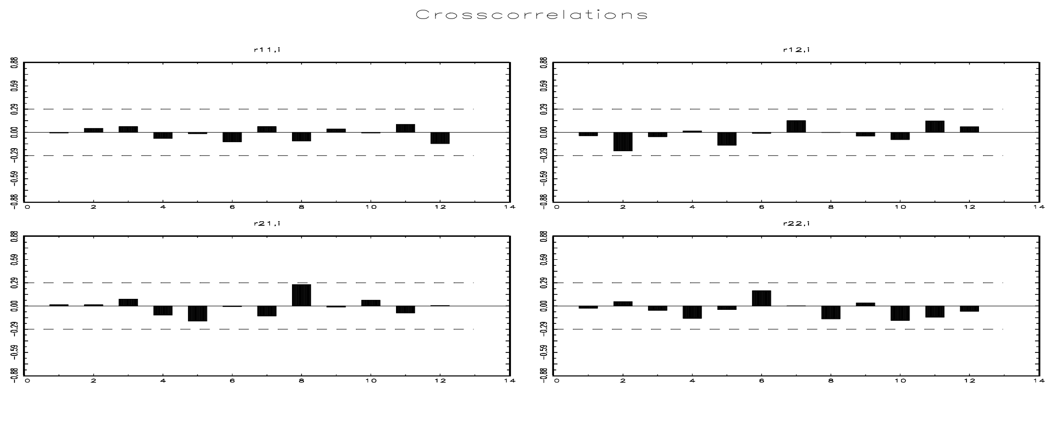
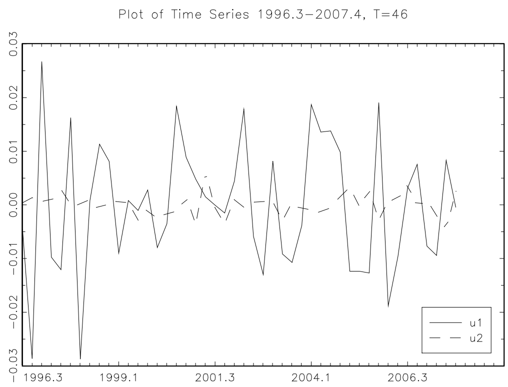
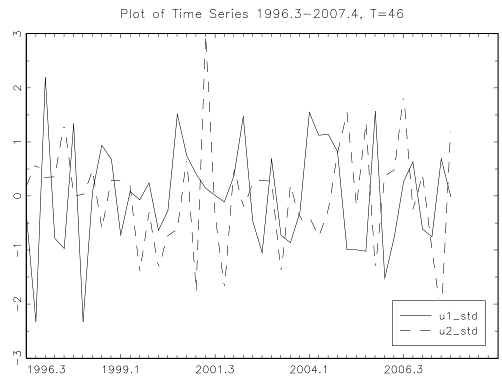



**Figure A6.2.** *VECM Restricted Model (VECM$^R$) - Graphical Diagnostic Checks*

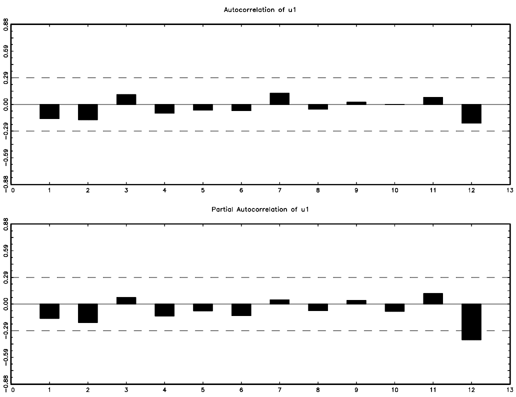
Residuals $u_{1t}$ and $u_{2t}$




Standardized residuals $u_{1t}$ and $u_{2t}$




AC and PAC of $u_{1t}$




AC and PAC of $u_{2t}$