CARGO VOLUME ANALYSIS OF THE TRANSPORT INDUSTRY OF UKRAINE

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Abstract: Ukraine has industrial achievements as the former Republic of the USSR. Today, Ukraine is an independent state, considered as an emerging-market country, trying to put in front its high potential to establish new economic relations with Western countries.

Integration with the European Union (EU) is actually considered to be an important subject of the foreign policy of Ukraine. In the context of a pragmatic and mutually beneficial cooperation between Ukraine and its European partners, the realisation of transport potential is of vital importance, see Academic S. Pyrozhkov, [27]. The authors of many economic papers, see Kondrya [23] and Kudriza [25] emphasise the necessity of development of new methods of economic sector analysis based on their principal features and the relationships between the sectors. These requests are analogue to those of leading Russian scientists like Academic S. Aivazian [1], who proposed to consider four major sectors of the Russian economy for analytical description and to separate power generation and freight transport into two sectors.

Ukrainian officials like Kondrya [23] and Kudriza [25] address requests of development of new methods of analyses in the transport complex, specially the detection of interrelationships between the modes of transport.

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This paper investigates monthly time series of the transport volume of Ukrainian cargo transit, namely road, pipeline, water and railway transport and proposes a cointegration analysis in the period of January 2003 to January 2010 with the aim to detect linear relationships between the cargo volumes.

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Key Words: transport, cargo volume analysis, time series,

1. Introduction

The Committee of Economic Reforms under the President of Ukraine, proposes a Program of Economic Reforms 2010-2014. This report mentions that the "Development of transport infrastructure is a catalyst for economic growth, as it facilitates the development of other sectors of the economy." Further it says: "The transit potential of the country is under utilised: freight traffic between Europe and Russia through Byelorussia is 5 times higher than through Ukraine. As a result, no new jobs are created in Ukraine in this sector and the state budget does not receive additional revenue sources.”

Actually in Russia and in Ukraine on high level State Administration great efforts to restructure the transport system are undertaken. The view of economy divided into several interdependent sectors has a long tradition in these countries. The leading Russian economist Aivazian [1] proposes to consider freight transport as a separate economic sector. The Ministry of Transport of the Russian Federation has presented in March 2010 the fundamental lines of developments of the transport system, emphasising to 'realise the transport strategies through a big-scaled project of controlling the transport system through a computerised and automatised system', see Kuzmina ([24], p. 18). Kuzmina reports the opinion of CEO of firms that it is essential 'to collect and treat the information on the transport activity in Russia' ([24], p. 22).

These texts clearly testify that high rank officials of Russia and Ukraine suggest to develop new methods to treat data issued from the respective transport systems and network. Moreover, they also ask to compare the efficiency of the Russian and Ukrainian transport system with the efficiency of the analogue

2It is also mentioned that Ukraine takes the 102nd place among 155 countries due to the index of logistic efficiency and that an improved transport control is needed to successfully reform the transport infrastructure. This step is possible only after careful analysis of the state of transport.
Western systems.

This paper intends to contribute to this discussion, detecting linear relationships between the cargo volumes.

In contrast to other industrial sectors, the transport sector does not produce material goods. Nevertheless, it is a very important segment of any economy. The output of the transport sector is transference and transport of goods and passengers. Modern transport systems are large complex systems and comprise different modes like road, pipeline, water and railway transport divided into urban and industrial transport. The goal of this kind of analysis is to create the instruments for monitoring the general situation of Ukrainian transport to determine new internal factors of development, to change external conditions, to discover eventual unbalanced utilisation of the transport system and to be able to propose changes of the loads.

In spite of the administrative independence between the modes of the transport system, the factual interdependence exerts an influence on cargo transition and the output of the whole industry.

The coherency of all modes of transport characterise the transport system of Ukraine and promotes a complex development for all economic regions. Regularity of activity of all fields of the industry depends on the level of development and the efficiency of the transport system.

The actual economic process of transition of Ukraine generates actually more and more direct contacts with the world economy. At a first stage it provokes an economic integration with the leading Western European states. This will bring growth of goods exchange between the countries. Moreover, the situation of Ukraine as a bridge for transit transport of cargo and passengers between the European states, Asia and the Near East has to be considered. That is the reason, why the transport system providing cargo and passenger transport throw Ukrainian territory must satisfy strong requirements of quality, regularity, reliability of transport and communication and safety for cargo and passengers. In other words, the state of the Ukrainian transport has to meet the requirements of the European standards.

2. Presentation of the Data

A fundamental characteristic of the transport system of Ukraine is the non stationarity of time series of cargo volumes of road, water, pipeline and railway transports. The impact of seasonality and significant random disturbances is important, see Figure 1.
2.1. The Railway Transport

The railway transport system is the best developed transport system in Ukraine. From the point of view of total length of railway networks, it takes the fourth place in the world after the USA, Russia and Canada. The railway volume of transport is 40 - 60 % of the total year volume. Concerning the passenger turnover it is 50 - 70% of total volume of transport.

The railway transport within the system of the Ukrainian transport communications plays an important role, because of the fact that the main Trans-European corridors pass through its territory: from East to West and from the Baltic to the Black Sea.
2.2. The Road Transport

The road transport occupies an important place in the cargo traffic and passenger transport\(^3\).

This paper deals with data connected to cargo transport only. That is why the road transport is on the second place after railway transport.

The automobile transport dominates in freight traffic on short distances (average distance of transportation of one cargo is about 20 km).

At the same time, the Ukrainian roads do not meet the European standards, particularly due to speed of movement, loading of the axis, provision of modern traffic signs and marking, sparse technical and medical care points, food and rest places, oil stations, telecommunications, etc. Actually roads of the first category with multi-row movement and with high speed are lacking.

The territory of Ukraine, especially in its Western part, is at crossroads of the transport corridors, connecting the countries of Southeast and Northwestern Europe; therefore with the further development of its economy it is necessary to increase the role of road transport, particularly the guarantee of operative and safe mode of transport.

2.3. The Pipeline Transport

The pipeline transport is a special mode of transport. It has no meaning for the transport in usual understanding, whose infrastructure is based on vehicles. But, pipeline transport is cheaper than railway transport and even water transport. It does not demand a big number of operators. The basic type of cargoes are liquids (oil, mineral oil) or gaseous products. Pipes stack on the earth or underground, and also on platforms. Cargo movement is carried out by pump stations.

2.4. The Water Transport

The water transport is the sea and river transport. Sea transport possesses the third place from the cargo turnover, after pipeline and railway transport, however, from the quantity of the cargo volume it takes an insignificant place (nearby 1 %), as well as the river transport.

The problems of the sea transport development are mainly connected with

\(^3\)The volume of passenger road transport surpasses 5-6 times the passenger railway transport. The bus transport conveys practically the same number of passengers as trolleybus, tram, railway, metro, taxi automobile, sea, river and aircraft transport together.
moral and physical deterioration of the ships and port equipments, especially for cargo processing means. The port infrastructure is not adapted to the new technologies. This reduces the productivity of the ports and of the transports connected with cargo processing as well.

The river transport does not play an important role in volumes of cargo and passenger transports. However, it surpasses all other kinds of transport from the income rate, basically, due to the transport of foreigners. The geography of the river transport is limited by the basins of the Dnieper and of the Danube, and also coastal waters of the Black Sea. That allows to deliver cargo and passengers to the river and sea ports of some countries of Central and Southeast Europe.

The river transport more than other modes of transport is under influence of natural seasonal changes, therefore its activity is closely coordinated with the road and railway transport.

The river transport of the state has secondary character which focuses on large cargo parties and cannot compete with railway transport from the point of view of tariffs and services. The efficiency of the river transport in Ukraine is lower (about 20 %) in comparison with the developed countries, having similar resources for this kind of transport.

2.5. The Air Transport

The air transport does not play an essential role in the total amount of cargo and passenger transport, though it is out of competition from the point of view of speed of delivery of passengers and urgent cargoes on big distances.

3. Preliminary Analyses

In this section all the preliminary steps taken for granted previous to a cointegration analysis are presented.

3.1. Presentation of the Time Series

Four monthly time series of the Ukrainian tracking industry, published by the State committee of Ukraine (Derzhkomstat), Figure 1, have been selected. They give the cargo volumes carried by road transport ($RT$) in 1000 tons, pipeline transport ($PT$) in million of tons, water transport ($WT$) in 1000 tons and railway transport ($RW$) in 1000 tons available for the period from January 2003 to January 2010. The monthly items of each series are numbered from
ADF-Residuals of parsimonious models with seasonals

Figure 2: Residuals of F Wald test procedure

$t = 1$ for 2003:01 to $T = 96$ for 2010:12. The series are organised into a vector $x_t = [x_{1t}, x_{2t}, x_{3t}, x_{4t}]' = [RT_t, PT_t, WT_t, RW_t]'$.

3.2. Stationarity Analysis through an ARIMA Model with Seasonals

Aiming parsimonious linear regression models through OLS F Wald tests. The monthly seasonality, $s = 12$ is clearly visible in the four time series, see Figure 1. It has to be considered. Thus, the approach aims to analyse the non-stationarity behaviour of the four time series, fundamentally guided by the idea to describe each of the four series by a parsimonious general AR model, comprising deterministic and stochastic seasonality. The deterministic seasonality is grasped through the $(s \times 1)$-vector $\Psi'_j$, $j = 1, \ldots, 4$ multiplied by the $(s \times 1)$-vector $D_t$, $D'_t = [D_{t,1}, \ldots, D_{t,12}]^4$. The stochastic seasonality is grasped

$^4$As the four analysed cargo volume time series start in January 2003 corresponding to $t = 1$, for every time $t = 1, \ldots, T$ the monthly index $t' := t \ (mod \ s) \in \{0, 1, 2, \ldots, s - 1\}$ is
through the $AR(p_j \geq s)$ parts. The constant of the models (2) is part of vectors $\Psi_j$, $j = 1, \ldots, 4$. There is linear trend and an iid error term $\varepsilon_t$. 

$$x_{jt} = \mu_j t + \Psi_j' D_t + \sum_{i=1}^{p_j} \delta_{ji} x_{j(t-i)} + \varepsilon_{jt}; \varepsilon_{jt} \sim iid(0, \sigma^2). \quad (2)$$

Moreover, simple algebra permits to convert the general $AR(p)$ model (2) to the equivalent "Augmented Dickey-Fuller (ADF) model" form, see Enders ([5], p. 225) and Hamilton ([14], p. 517), see Emmenegger & Pervukhina, [4]),

$$\Delta x_{jt} = \mu_j t + \Psi_j' D_t + (\beta_j - 1) x_{j(t-1)} + \sum_{i=1}^{p_j-1} \gamma_{ji} \Delta x_{j(t-i)} + \varepsilon_{jt}. \quad (3)$$

The models (2) allow to have a first insight into the nature of stationarity and seasonality of the time series ([4]). First, the parameters of the most parsimonious models (2), describing the series $x_{jt}$, $j = 1, \ldots, 4$, are estimated. The first point is to chose the degrees of the general $AR(p)$ models (3). It is set to $p_j = 13$ to grasp the eventually existing stochastic seasonality, estimating in a first step a full model with seasonal dummies. The reduction of parameters is conducted through a cascade of consecutive joint OLS F Wald tests, leading to a final parsimonious models, presented later.

The cascade of decision comprises following steps:

1. Compute a general $AR$-model (3) (A) for the parameters ($\beta_j$, $\mu_j$, vector $\Psi_j$, $\gamma_{ij}$, $i = 1, \ldots, p_j$)

2. The null hypothesis for the estimated parameters is that they are zero.

3. A series of $T-\text{statistics}$ gives for every estimated parameter the $p-value$ of the null hypothesis.$^5$

4. All parameters with relatively high $p-values$ of the $T-\text{Statistics}$, (0.05 being the lowest limit, but most of the $p-values$ are above 0.5) are selected and tested together through a joint F Wald test.

computed and the $s$ vector components $D_{t,i}$, $l = 1, \ldots, s$ are determined as

$$D_{t,i} = \begin{cases} 1 & t \ (mod \ s) := l' = t \\ 0 & t \ (mod \ s) := l' \neq t \end{cases}, \quad (1)$$

see Hansen & Juselius ([15]).

$^5$The lower the $p-value$, the less likely under the null hypothesis the analysed parameter is zero and consequently the more "significant" the result is, (http://en.wikipedia.org/wiki/P-\text{value}).
5. When the $p$-value of this joint F Wald test is (comfortably) higher than 0.05, the null hypothesis that all the selected parameters are zero is accepted.

6. A further more parsimonious general AR-model (3) (B) for the remaining subset of the parameters $(\beta_j, \mu_j$, vector $\Psi_j$, $\gamma_{ij}$, $i = 1,...p_j$, supposed to be different from zero, is computed.

7. The steps 2), 3), 4), 5) are again applied for this model (B).

8. The process is iterated, until all the $T$-statistics of the remaining parameters are lower than 0.05.

9. The last general AR-model is kept as the most parsimonious model. The Durbin-Watson test value is also verified at every step and should vary comfortably around 2. Thus, the reduction of parameters is safely done.

At the end, there remains four models that can no longer be reduced, because all the parameters are significantly different from zero, that means all the $p$-values of the $T$-statistics are lower than 0.05. They are presented here\(^6\).

First, the modelization of series of road transport volumes $RT_t$, the standard deviation is indicated in brackets below the estimated coefficients:

$$RT_t = 0.907 RT_{t-1} - 0.395 DRT_{t-1} + \Psi'_1 D_t + \varepsilon_t; \; \varepsilon_t \sim iid(0, \sigma^2 = 1.2627)$$ (4)

$$\Psi'_1 = [-0.40, 0.306, 2.39, 2.16, 2.39, 3.10, 1.70, 1.64, 1.77, 0.0]$$

Second, the modelization of series of pipeline transport volumes $PT_t$:

$$PT_t = 0.640 PT_{t-1} - 0.028 t + \Psi'_2 D_t + \varepsilon_t; \; \varepsilon_t \sim iid(0, \sigma^2 = 1.2139)$$ (5)

$$\Psi'_2 = [-8.03, 6.48, 7.97, 5.29, 6.86, 5.19, 6.52, 6.19, 7.16, 0]$$

Third, the modelization of series water transport volumes $WT_t$:

$$WT_t = 0.895 WT_{t-1} + \Psi'_3 D_t + \varepsilon_t; \; \varepsilon_t \sim iid(0, \sigma^2 = 0.0427)$$ (6)

$$\Psi'_3 = [-0.41, 0.17, 0.49, 0.23, 0.37, 0.35, 0.28, 0.19, 0.26, 0.0]$$

Forth, the modelization of series of railway transport volumes $RW_t$:

$$RW_t = 0.934 RW_{t-1} + 0.306 DRW_{t-1} + \Psi'_4 D_t + \varepsilon_t; \; \varepsilon_t \sim iid(0, \sigma^2 = 3.8799)$$ (7)

$$\Psi'_4 = [0, 2.31, 8.42, 2.68, 0, 1.66, 3.86, 3.68, 1.99, 3.30, 0, 1.67]$$

\(^6\)All the computations are performed with the software package, RATS and CATS from Estima, Illinois, USA, see Doan [3]
The key results from the models (4,5,6,7) are, see Table 1: a) All the $\gamma_i$ are near 1, col. (6), indicating the presence of a non seasonal unit root, b) all the series exhibit strong seasonal dummies, indicating deterministic seasonality, c) no series exhibit significant parameters $\delta_{j,12}$ or $\delta_{j,13}$, indicating absence of stochastic seasonality. An augmented Dickey-Fuller (ADF) test with no trend, except for $PT_t$, is performed, optimal lags are calculated through the AIV/BIC/HQ/MAIC criterions. Further main results are presented, see in Table 1: col. (3) lists the validated significant parameters, all the series exhibit seasonal dummies, only $PT_t$ has trend, col. (4) shows the degrees of the models, col. (5) shows the thoroughly acceptable Durbin-Watson statistics (DW), col (6) shows the values of the coefficients $\gamma_j$, col. (7) shows the standard error of the coefficient $\gamma_j$, col. (8) shows the optimal lags $p$ for the ADF-test, col. (9) indicates the ADF-test statistics, col. (10) indicates the degree of integration of the time series. Only the series $WT_t$ appear to be stationary $I(0)$, having no non seasonal unit root, see col. (9). The three other series $RT_t$, $PT_t$ and $RW_t$ appear to be non-stationary $I(1)$.

The autocorrelation functions of the residuals of models (4,5,6,7), presented in Figure 2, no longer indicate the presence of serial correlation.

<table>
<thead>
<tr>
<th>j</th>
<th>ser.</th>
<th>dum.</th>
<th>$p_j$</th>
<th>DW</th>
<th>$\gamma_j$</th>
<th>st.err.</th>
<th>p</th>
<th>ADF-test</th>
<th>I(d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$RT_t$</td>
<td>$\Psi$</td>
<td>2</td>
<td>1.8634</td>
<td>0.9066</td>
<td>0.0178</td>
<td>0</td>
<td>-3.615***</td>
<td>I(1)</td>
</tr>
<tr>
<td>2</td>
<td>$PT_t$</td>
<td>$\mu, \Psi$</td>
<td>1</td>
<td>2.2019</td>
<td>0.6398</td>
<td>0.0788</td>
<td>2</td>
<td>-6.194***</td>
<td>I(1)</td>
</tr>
<tr>
<td>3</td>
<td>$WT_t$</td>
<td>$\Psi$</td>
<td>1</td>
<td>2.2686</td>
<td>0.8947</td>
<td>0.0207</td>
<td>3</td>
<td>-2.570*</td>
<td>I(0)</td>
</tr>
<tr>
<td>4</td>
<td>$RW_t$</td>
<td>$\Psi$</td>
<td>2</td>
<td>2.0464</td>
<td>0.9346</td>
<td>0.0105</td>
<td>6</td>
<td>-7.429***</td>
<td>I(1)</td>
</tr>
</tbody>
</table>

Table 1: Parsimonious $AR(p)$ models, degree of integration

For the pipeline transport volume $PT_t$, the trend gradient is clearly significant and negative, $\mu = -0.02809$ at minus 2 percents for a period of 8 year.

 Only pipeline and railway transport exhibit significant model levels (last value in vector $\Psi_j$. The HEGY test applied to the four simulated time series $Y_t$, $Z_t$, $V_t$ and $W_t$ is presented. The critical values are taken in Franses [8], p. 203, for 120 observations and Franses & Hobjin [10]. In Tables 2, the notation ** means after a number as usual significant at 5%, $\pi_{\text{odd}}$ and $\pi_{\text{even}}$ mean t-test for even and off indices of $\pi_i$.

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7The RATS routine autoselect.src is used for that purpose.
8The stars indicate the significance level: *** at 1%, ** at 5%, * at 10%
The popular HEGY test, see Hylleberg [16] is applied to investigate stochastic seasonality. Table 2 gives the results. The HEGY test for the four time series confirms presence of stochastic seasonality. This is in contradiction with the above results, obtained from the models (4,5,6,7), postulating no stochastic seasonality but deterministic seasonality. Moreover, Emmenegger and Pervukhina have shown, see [4], that for "short time series with no seasonal unit roots the HEGY test may incorrectly not reject the hypothesis of existence of seasonal unit roots". Indeed, there is here the case of short time series (T=96).

The authors decided to trust in the results, obtained from the models (4,5,6,7), postulating deterministic seasonality and excluding stochastic seasonality.

### 3.4. Non-Stationarity of the Ukrainian Cargo Volume Time Series

The unit root investigation suggest, see Table 1, col. (8-10) suggest that the series $RT_t$, $PT_t$ and $RW_t$ are non-stationary $I(1)$, whereas the series $WT_t$ is stationary $I(0)^9$.

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9Clearly, the first differences of the four series are all stationary. This result is not presented here).
4. Cointegration Analysis

In the present analysis one uses the definition of cointegration, as it is presented by Lütkepohl ([26], p. 352). Lütkepohl calls a $K$-dimensional process $x_t$ integrated of order $d$, briefly, $x_t \sim I(d)$, if $\Delta^d x_t$ is stable and $\Delta^{d-1} x_t$ is not stable.\[^{10}\]

The $I(d)$ process $x_t$ is called cointegrated, if there is a linear combination $c x_t$ which is integrated of order less than $d$. If there is just one $I(d)$ component in $x_t$ and all other components are stable ($I(0)$) the vector $x_t$ is $I(d)$ according to our definition, because $\Delta^d x_t$ is stable and $\Delta^{d-1} x_t$ is not.

This definition differs from that given by Engle & Granger [7] in that one does not exclude components of $x_t$ with order of integration less than $d$.

But, in the present analysis, one encounters exactly the situation that not all time series for which one looks for cointegration are integrated of the same order.

4.1. Setting up a VAR(p) Model

Analysing the definition of cointegration, it is evident that the VAR models are the prerogatives of cointegration analysis. Therefore, a vector autoregressive model of $p$ lags, designed as $VAR(p)$, with linear trend and seasonal dummies is set up,

$$x_t = \alpha + \mu t + \Psi D_t + \sum_{j=1}^{p} A_j x_{t-j} + \epsilon_t \ ; \ t = 1, \ldots, T,$$

(8)

where $\alpha$ is the $(k \times 1)$-vector of intercept terms, $\mu$ is the trend $(k \times 1)$-vector, $\Psi$ is the $(k \times k)$-matrix of seasonal dummies, $A_j$ are $(k \times k)$-matrices of coefficients and $\epsilon_t$ is a $(k \times 1)$-vector of error terms. For parameter estimation, the least squares method is applied, the order of the model $p$ is determined with the help of the Akaike Information Criterion (AIC).\[^{11}\]

The model (8) represents a vector autoregressive model $VAR(p)$ that can be transformed into the error-correction form. Thus, the level $\alpha$ disappears, the

\[^{10}\]A $VAR(1)$ process $x_1 = \nu + A_1 x_0 + u_1$ is stable, if all eigenvalues of the matrix $A_1$ have modulus less than 1 ([26], p. 11). Moreover, any $K$-dimensional $VAR(p)$ process can be described as a $Kp$-dimensional $VAR(1)$ process, whose matrix $A_1$ is the so-called ‘companion matrix’. The eigenvalues of that ‘companion matrix’ can be calculated with the software package RATS-CATS, see Doan [3]. This means that the property of stability can be verified in general $VAR(p)$ processes. Also, a stable process is stationary ([26], Proposition 2.1, p. 20).

\[^{11}\]The RATS-routine @selectvarlag, written by Tom Doan in June 2005, see also RATS 7 manual [3], is used to calculate the AIC criterion values.
trend gradient $\mu$ becomes the level, the dummy seasonals $\tilde{\Psi}$ are transformed to $\Psi$. The corresponding algebra is presented in Hamilton, see ([14], p. 517). One gets

$$\Delta x_t = \mu + \Pi x_{t-1} + \Psi D_t + \sum_{j=1}^{p-1} \Pi_j \Delta x_{t-j} + \varepsilon_t \quad; \quad t = 1, \ldots, T,$$

(9)

with matrix $\Pi = I - A_1 - A_2 - \ldots - A_p$. The rank of $\Pi$ is equal to the number of independent cointegrating vectors. If $\text{rank}(\Pi) = 0$, the matrix is null and (9) is the usual $VAR(p)$ model in first differences with no cointegration space. Instead, if $\Pi$ is of rank $\Pi = k$, the vector process is stationary. For the other cases, $0 < \text{rank}(\Pi) < k$, there are one or more cointegrating vectors. The number of distinct cointegrating vectors is obtained by calculating the number of significant eigenvalues $\lambda$ of equation $|\lambda S_{kk} - S_{k0}S_{00}^{-1}S_{0k}| = 0^{12}$.

### 4.2. The Economic Question to be Analysed

The purpose of this paper is to propose, due to the requirements of Ukrainian and Russian officials, see Pyrozhkov, [27], Kondrya [23], Kudriza [25], Aivazian [1]. In the above context we would like to know, if there are relations between cargo volumes carried by different mode of transport. Are they stable or not? The present analyses has the purpose to discover such linear relations between the four cargo transport volume time series $RT_t, PT_t, WT_t, RW_t$ for some of the real coefficients $\alpha, \pi_1, \pi_2, \pi_3 \neq 0$, in a way that the equation

$$RT_t = \alpha + \pi_1 RW_t + \pi_2 PT_t + \pi_3 WT_t + \varepsilon_{1t} \quad; \quad \varepsilon_{1t} \sim iid(0, \sigma^2).$$

(10)

is valid for all moments $t \in P = \{2003 : 1, 2010 : 12\}$. The cointegration methodology of Johansen will be applied to find these linear relations between two, three or four of the considered time series.

### 4.3. The Johansen Methodology to Calculate Cointegration Relations

Simultaneously two, three or four of the time series are selected and analysed on the period $P = \{2003 : 1, \ldots, 2010 : 12\}$, $|T| = 96$. A multivariate vector autoregressive (VAR) model in error-correction form (9) is set. The optimal

12The matrices $S_{ij} = T^{-1} \sum_{t=1}^{T} R_{it}R_{jt}'$, $i, j = 0, \ldots, k$ are product moment matrices of residuals $R_{it}$. The residuals $R_{it}$ result from the regressions of $X_{t-i}$ on the lagged differences $\Delta X_t$, see Johansen [17, 18].
number of \( p \) lags of the corresponding \( VAR(p) \) is determined with the AIC criterion\(^\text{13}\).

The maximum eigenvalue cointegration rank test \( \lambda_{max} \) of Johansen and the trace cointegration rank test \( \lambda_{\text{trace}} \) [18, 19] have been applied to verify the existence of cointegration subspaces. No constant has been chosen in the unrestricted model, see Hansen, ([15], p. 14]). The calculations have been done, implying always dummy seasonals. The cointegration relation has been set with (dettrend=cimean) or without (dettrend=none) constants \( \alpha \). In a first approach, the selected time series, the estimated lags of the \( VAR \) model, and the dettrend parameter (10) are shown in Table 3.

\[
\begin{array}{|c|c|c|}
\hline
\text{subset} & \text{lags} & \text{dettrend} \\
(1) & (2) & (3) \\
\hline
\{RT_t, RW_t\} & 2 & \text{none} \\
\{RT_t, WT_t\} & 1 & \text{cimean} \\
\{RT_t, RW_t, WT_t\} & 2 & \text{none} \\
\{RT_t, RW_t, PT_t, WT_t\} & 3 & \text{none} \\
\{RT_t, RW_t, PT_t\} & 3 & \text{none} \\
\hline
\end{array}
\]

Table 3: Selected time series, lags and constant in cointegration relation

4.4. The Johansen Cointegration Rank Tests

In this subsection the \textit{Johansen cointegration rank test} statistics are summarised [18, 19]. There is the maximum eigenvalue and the trace test, whose critical values have been tabulated first by Johansen and Juselius [20, 21].

The **trace statistics**. If the null hypothesis states that the matrix has \( \text{rank}(\Pi) = r \leq k \) (9) against the alternative hypothesis \( \text{rank}(\Pi) > k \), then use the \( \lambda_{\text{trace}} \) statistics, see Enders [6].

\[
\lambda_{\text{trace}} = -T \sum_{i=r+1}^{n} \ln(1 - \hat{\lambda}_i) \tag{11}
\]

The **maximum eigenvalue statistics**. If the null hypothesis states that the matrix has \( \text{rank}(\Pi) = r \) (9) against the alternative hypothesis \( \text{rank}(\Pi) =

\(^\text{13}\)The AIC criterion is calculated with the RATS-routine @varlagselect.src, see Doan [3]
The $\lambda_{\text{max}}$ and the $\lambda_{\text{trace}}$ test are used together and the standard tables produced by CATS will be presented later, the interpretation of the results are straightforward.

**Procedure of the Johansen cointegration rank test.** CATS calculates all the eigenvalues, the $\lambda_{\text{max}}$ and the $\lambda_{\text{trace}}$ statistics and presents them together with the critical values $\lambda_{\text{max}}(1-\alpha)$ and $\lambda_{\text{trace}}(1-\alpha)$ for the significance level set here at $\alpha = 0.1$. The eigenvalues appear in decreasing order and the hypothetical rank value $r$ in ascending order.

In the next subsections, the cointegration analyses of subsets of cargo transport time series, realised with success, are presented. The different modes of restriction, see Hansen ([15], p. 5), applied to the level $\alpha$ of the calculated models (8) are explained, here the trend $\mu$ is restricted to zero in all the models.
4.5. Cointegration Analysis of the Series \( RT_t \) and \( RW_t \)

Cointegration of the volume of road transport \( RT_t \) and railway transport \( RW_t \) is investigated, \( k = 2 \) variables.

1. No constant restricted to the cointegration space. Due to the AIC criterion, the lag \( p = 2 \) is set for the \( VAR \) model\(^\text{14}\). The \( \lambda_{\text{max}} \) and \( \lambda_{\text{trace}} \) statistics are displayed along with the critical values of Johansen and Nielsen [19] for \( \alpha = 0.1 \) in the Table 4. The rank tests indicate that the eigenvalue

<table>
<thead>
<tr>
<th>eigenvalues</th>
<th>( \lambda_{\text{max}} )</th>
<th>( \lambda_{\text{trace}} )</th>
<th>( H_0 )</th>
<th>( H_1 )</th>
<th>( \lambda_{\text{max}90} )</th>
<th>( \lambda_{\text{trace}90} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \lambda_1 ) = 0.1053</td>
<td>10.46</td>
<td>10.47</td>
<td>( r = 0 )</td>
<td>( p - r = 2 )</td>
<td>7.37</td>
<td>10.35</td>
</tr>
<tr>
<td>( \lambda_2 ) = 0.0001</td>
<td>0.01</td>
<td>0.01</td>
<td>( r = 1 )</td>
<td>( p - r = 1 )</td>
<td>2.98</td>
<td>2.98</td>
</tr>
</tbody>
</table>

Table 4: Johansen cointegration rank tests for \( RT_t \) and \( RW_t \)

\( \lambda_1 = 0.1053 \) is significant\(^\text{15}\), whereas the second eigenvalue \( \lambda_2 = 0.0001 \) is not significant.\(^\text{16}\). The cointegration rank tests indicate rank \( r = 1 \). Then, the absolute values of both first of the \( kp = 4 \) eigenvalues of the 'companion matrix' \( A_1 \) are computed, see Juselius ([22], p. 50). There is \( u = 1 \) eigenvalue equal 1.0005. The second is 0.8544, too 'far away' from the border of the unit circle, indicating the rank \( r = k - u = 1 \). This means that the Johansen cointegration rank tests and the 'companion matrix' indicate cointegration rank \( r = 1 \).

There is no longer serial correlation in the residuals, as the LM test of Breusch-Godfrey [11], [2] shows, indeed, one finds: \( LM(4), P(\chi^2(4) \geq 3.886) = 0.42 \). Then, the distributions of the residuals are far from normal. But with these test results, one cointegration relation can be justified and calculated

\[
\hat{RT}_t(RW_t) = 0.333RW_t \quad ; \quad t = 2003 : 3 - 2010 : 12. \quad (13)
\]

\(^{14}\)The AIC criterion are calculated for every model with the RATS-routine \@varlagselect.src, see Doan [3]

\(^{15}\)The statistics \( \lambda_{\text{max}} = 10.46 > \lambda_{\text{max}(1-\alpha)} = 7.37 \), means that the null hypothesis \( r = 0 \) is rejected against the alternative hypothesis \( r = 1 \). Then, the statistics \( \lambda_{\text{trace}} = 10.47 > \lambda_{\text{trace}(1-\alpha)} = 10.35 \), means that the null hypothesis \( r = 0 \) is rejected against the alternative hypothesis \( r > 0 \). Thus, both rank tests postulate \( r = 1 \).

\(^{16}\)The statistics \( \lambda_{\text{max}} = 0.01 < \lambda_{\text{max}(1-\alpha)} = 2.98 \), means that the null hypothesis \( r = 1 \) is not rejected against the alternative hypothesis \( r = 2 \). Then, the statistics \( \lambda_{\text{trace}} = 0.01 < \lambda_{\text{trace}(1-\alpha)} = 2.98 \), means that the null hypothesis \( r\neq1 \) is not rejected against the alternative hypothesis \( r > 1 \). Thus, both rank tests postulate \( r = 1 \).
The cointegration relation (13) is graphed in Figure 3, upper left corner.\(^{17}\)

2. A constant restricted to cointegration space. Due to the AIC criterion, the lag \(p = 2\) is set for the VAR model. The \(\lambda_{\text{max}}\) and \(\lambda_{\text{trace}}\) statistics are displayed along with the critical values of Johansen and Nielsen [19] for \(\alpha = 0.1\) in the Table 5. The Johansen cointegration rank tests indicate that

<table>
<thead>
<tr>
<th>eigenvalues</th>
<th>(\lambda_{\text{max}})</th>
<th>(\lambda_{\text{trace}})</th>
<th>(H_0)</th>
<th>(H_1)</th>
<th>(\lambda_{\text{max90}})</th>
<th>(\lambda_{\text{trace90}})</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\lambda_1 = 0.1207)</td>
<td>12.10</td>
<td>16.24</td>
<td>(r = 0)</td>
<td>(p - r = 2)</td>
<td>10.29</td>
<td>17.79</td>
</tr>
<tr>
<td>(\lambda_2 = 0.0431)</td>
<td>4.14</td>
<td>4.14</td>
<td>(r = 1)</td>
<td>(p - r = 1)</td>
<td>7.50</td>
<td>7.50</td>
</tr>
</tbody>
</table>

Table 5: Johansen cointegration rank tests for \(RT_t\) and \(RW_t\)

the eigenvalue \(\lambda_1 = 0.1207\) is significant, whereas \(\lambda_2 = 0.0431\) is not. The cointegration rank tests indicate rank \(r = 1\). Then the absolute values of both first of the \(kp = 4\) eigenvalues of the ‘companion matrix’ \(A_1\) are computed, see Juselius ([22], p. 50). There are \(u = 2\) eigenvalues equal to 0.8892, both ‘near to’ the border of the unit circle, indicating the rank \(r = k - u = 0\). Let’s trust in the results of the Johansen cointegration rank tests indicating rank \(r = 1\).

There is no longer serial correlation in the residuals, as the LM test of Breusch-Godfrey [11], [2] shows, indeed, one finds: \(LM(4), P(\chi^2(4) \geq 3.908) = 0.42\). Then, the distributions of the residuals are far from normal. But with these test results, one cointegration relation can be justified and calculated

\[
\hat{RT}_t(RW_t) = 0.587RW_t - 9.839 \quad ; \quad t = 2003 : 3 - 2010 : 12. \quad (14)
\]

The cointegration relation (14) is graphed in Figure 3, upper right corner.

4.6. Cointegration Analysis of the Series \(RT_t\), \(RW_t\) and \(WT_t\)

No constant restricted to cointegration space. Cointegration of \(k = 3\) variables, the volumes of road transport \(RT_t\), water transport \(WT_t\) and railway transport \(RW_t\) is investigated. Due to the AIC criterion, lag \(p = 2\) is set for the

\(^{17}\)The cointegration analysis results in equation (13), stating that the volumes of the road transport is estimable through a multiplication of the volume of the railway transport by the number 0.333 for the whole period 2003:1 - 2010:12. As usual in this context, the error terms of the equations and the estimated standard deviations of the estimated multiplicators are not indicated in the cointegration equation, see Enders ([5]), Juselius ([22]). But these values are available in the RATS-journals of computation with other informations.
Cointegration of "RT" and "RT(RW,WT,PT)", detrend=none

VAR model. The $\lambda_{\text{max}}$ and $\lambda_{\text{trace}}$ statistics are displayed along with the critical values of Johansen and Nielsen [19] for $\alpha = 0.1$ in the Table 6. Clearly, the rank tests indicate that the eigenvalues $\lambda_1 = 0.0912$, $\lambda_2 = 0.0244$ and $\lambda_3 = 0.0000$ are not significant. But, let’s remark that $\lambda_1 = 0.0912 \, 0.1$. The cointegration rank tests indicate rank $r = 0$. On the other hand, the two first absolute values of the $kp = 6$ eigenvalues of the ‘companion matrix’ $A_1$ are near one, namely $1.000$ and $0.9644$, the others are $\lambda \leq 0.8630$, distant from the border of the unit circle, thus, $u = 2$. Let’s conclude from the calculations of eigenvalues of the ‘companion matrix’ that the rank $r = k - u = 1$.

There is no longer serial correlation in the residuals, as the Lagrange Multiplier (LM) test of Breusch-Godfrey [11], [2] shows. The LM test is realised for 4 lags: $LM(4)$, $P(\chi^2(9) \geq 9.644) = 0.38$. Then, the distributions of the residuals are far from normal. But with these test results, the cointegration relation can be justified and calculated

$$\hat{RT}_t(RW_t, WT_t) = 0.454RW_t - 2.928WT_t; \ t = 2003 : 3 - 2010 : 12. \quad (15)$$
4.7. Cointegration Analysis of the Series $RT_t$, $RW_t$ and $TP_t$

No constant restricted to cointegration space. Cointegration of the $k = 3$ variables, the volumes of road transport $RT_t$, pipeline transport $TP_t$ and railway transport $RW_t$ is investigated. Due to the AIC criterion, lag $p = 3$ is set for the VAR model. The $\lambda_{\text{max}}$ and $\lambda_{\text{trace}}$ statistics are displayed along with the critical values of Johansen and Nielsen [19] for $\alpha = 0.1$ in the Table 7. Clearly,

\[
\begin{array}{cccccccc}
\text{eigenvalues} & \lambda_{\text{max}} & \lambda_{\text{trace}} & H_0 & H_1 & \lambda_{\text{max90}} & \lambda_{\text{trace90}} \\
(1) & (2) & (3) & (4) & (5) & (6) & (7) \\
\lambda_1 = 0.0912 & 8.80 & 10.13 & r = 0 & p - r = 3 & 11.23 & 21.58 \\
\lambda_2 = 0.0244 & 1.34 & 1.34 & r = 1 & p - r = 2 & 7.37 & 10.35 \\
\lambda_3 = 0.0000 & 0.00 & 0.00 & r = 2 & p - r = 1 & 2.98 & 2.98 \\
\end{array}
\]

Table 6: Johansen cointegration rank tests for $RT_t$, $WT_t$ and $RW_t$

The cointegration relation (15) is graphed in Figure 3, lower left corner. The quality of cointegration is not perfected, as presumed form the rank tests.

The rank tests indicate that the eigenvalue $\lambda_1 = 0.1574$ is significant, whereas $\lambda_2 = 0.0239$ and $\lambda_3 = 0.0054$ are not. The cointegration rank tests indicate rank $r = 1$. Then the absolute values of the two first of the $kp = 9$ eigenvalues of the ‘companion matrix’ $A_1$ are ‘near to’ the unit, namely 0.9963 and 0.9634, whereas all the others are distant from the unit circle, $|\lambda| < 0.5871$. Therefore, set $u = 2$ and $r = k - u = 1$ for the rank. This means that the ‘companion matrix’ and the $\lambda$-test both indicate rank $r = 1$.

There is no longer serial correlation in the residuals, as the Lagrange Multiplier (LM) test of Breusch-Godfrey [11], [2] shows. The LM test is realised for 4 lags: $LM(4)$, $P(\chi^2(9) \geq 6.940) = 0.64$. Then, the distributions of the residuals are far from normal. But with these test results, the cointegration relation can
be justified and calculated

\[ \hat{RT}_t(RW_t, TP_t) = 0.633RW_t - 0.723TP_t \quad ; \quad t = 2003 : 3 - 2010 : 12. \]  \hspace{1cm} (16)

The cointegration relation (16) is graphed in Figure 3, lower right corner.

4.8. Cointegration Analysis of the Series \(RT_t, PT_t, WT_t\) and \(RW_t\)

No constant restricted to cointegration space. Cointegration of the \(k = 4\) variables, the volumes of road transport \(RT_t\), pipeline transport \(PT_t\), water transport \(WT_t\) and railway transport \(RW_t\) is performed. Due to the AIC criterion, lag \(p = 3\) is set for the VAR model. The \(\lambda_{\text{max}}\) and \(\lambda_{\text{trace}}\) statistics are displayed along with the critical values of Johansen and Nielsen [19] for \(\alpha = 0.1\) in the Table 8. Clearly, the \(\lambda_{\text{max}}\) rank test indicates that the eigenvalue \(\lambda_1 = 0.1599\) is significant, the \(\lambda_{\text{trace}}\) rank test does not indicate significance of the eigenvalue \(\lambda_1 = 0.1599\), whereas \(\lambda_2 = 0.0832\), \(\lambda_3 = 0.0117\) and \(\lambda_4 = 0.0031\) are not significant. Therefore the cointegration rank tests indicate rank \(r = 1\). Then the absolute values of the two first of the \(kp = 9\) eigenvalues of the 'companion matrix' \(A_1\) are 'near to' the unit, namely 0.9963 and 0.9634, whereas all the others are distant from the unit circle, \(|\lambda| < 0.5871\), indicating the rank \(r = k - u = 1\). This means that the 'companion matrix' and the \(\lambda\)-test both indicate rank \(r = 1\).

<table>
<thead>
<tr>
<th>eigenvalues</th>
<th>(\lambda_{\text{max}})</th>
<th>(\lambda_{\text{trace}})</th>
<th>(H_0)</th>
<th>(H_1)</th>
<th>(\lambda_{\text{max}}^{90})</th>
<th>(\lambda_{\text{trace}}^{90})</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\lambda_1 = 0.1599)</td>
<td>15.86</td>
<td>25.12</td>
<td>(r = 0)</td>
<td>(p - r = 4)</td>
<td>15.00</td>
<td>36.58</td>
</tr>
<tr>
<td>(\lambda_2 = 0.0832)</td>
<td>7.90</td>
<td>9.26</td>
<td>(r = 1)</td>
<td>(p - r = 3)</td>
<td>11.23</td>
<td>21.58</td>
</tr>
<tr>
<td>(\lambda_3 = 0.0117)</td>
<td>1.07</td>
<td>1.35</td>
<td>(r = 2)</td>
<td>(p - r = 2)</td>
<td>7.37</td>
<td>10.35</td>
</tr>
<tr>
<td>(\lambda_4 = 0.0031)</td>
<td>0.28</td>
<td>0.28</td>
<td>(r = 3)</td>
<td>(p - r = 1)</td>
<td>2.98</td>
<td>2.98</td>
</tr>
</tbody>
</table>

Table 8: Johansen cointegration rank tests for \(RT_t, PT_t, WT_t\) and \(RW_t\)

is significant, the \(\lambda_{\text{trace}}\) rank test does not indicate significance of the eigenvalue \(\lambda_1 = 0.1599\), whereas \(\lambda_2 = 0.0832\), \(\lambda_3 = 0.0117\) and \(\lambda_4 = 0.0031\) are not significant. Therefore the cointegration rank tests indicate rank \(r = 1\). Then the absolute values of the two first of the \(kp = 9\) eigenvalues of the 'companion matrix' \(A_1\) are 'near to' the unit, namely 0.9963 and 0.9634, whereas all the others are distant from the unit circle, \(|\lambda| < 0.5871\), indicating the rank \(r = k - u = 1\). This means that the 'companion matrix' and the \(\lambda\)-test both indicate rank \(r = 1\).

There is no longer serial correlation in the residuals, as the Lagrange Multiplier (LM) test of Breusch-Godfrey [11], [2] shows. The LM test is realised for 1 and 4 lags: \(LM(4), P(\chi^2(16) \geq 16.835) = 0.40\). Then, the distributions of the residuals are again far from normal. But with these test results, the cointegration relation can be justified and calculated

\[ \hat{RT}_t(RW_t, PT_t, WT_t) = 0.985RW_t - 0.694PT_t - 7.951WT_t \]  \hspace{1cm} (17)

The cointegration relation (17) is graphed in Figure 4.
Conclusions

This study determined with success five linear cointegration relations (13), (14), (15), (16), (17) among the Ukrainian cargo volume time series of road transport $RT_t$, pipeline transport $PT_t$, water transport $WT_t$ and railway transport $RW_t$ over the whole period $P = [2003 : 3 - 2010 : 12]$, all resulting from identified 1-dimensional cointegration spaces.

From the identified cointegration relations one learns that the cargo volume of road transport is constantly about 1/3 of the cargo volume of railway transport for the whole period $P$. It is also interesting to see that the road transport volume can be expressed as a combination of the volumes of the three other transport mode over the whole period $P$. This cointegration relation reveals the mutual dependencies of the four cargo transport modes.

The discovered stable relations between different modes of freight transport, valid in the period [2003-2010] do not argue for cardinal changes in the actual structure of the Ukrainian transport system.

This is the suggestion of this study to the subjects discussed in the Ukrainian President’s Program of Economic Reforms 2010-2014, presented in Kharkiv, June 2010.

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References


