This article attempts to verify the phenomenon of price transmission between wholesale markets of carrots in Poland. Determining the level of spatial integration of markets will indicate their efficiency and thus can make it easier for producers to take decisions about where to sell their products. The empirical data includes daily quotations of carrot prices on fruit and vegetable wholesale markets in Bronisze, Kalisz, Poznań, Radow and Sandomierz. The time range of the studies covered the years 2011–2016. This research is based on dynamic econometric methods (sVAR model) and the Granger causality tests. The research carried out using dynamic econometric methods has shown that despite the occurrence of significant variation in the level of carrot prices in the examined markets, their interaction was observed. Moreover, the results of the sVAR model estimation indicate that the changes in carrot prices on a particular market are stronger influenced by the price changes from the same market. This is an autoregressive effect. It also means that the carrot price information coming from other wholesale markets (price transmission effect) has a much weaker effect.

Key words: price transmission, sVAR model, Granger causality test, wholesale market, vegetable prices

INTRODUCTION

The market for agricultural products is subject to the universal laws of market economy. However, it has specific characteristics which in many cases result in atypical market behaviour compared to other markets. Nevertheless, the most important principle shaping the level of prices on the agricultural products market is the law of supply and demand [Hamulczuk et al. 2012]. The price relationship between agricultural markets at the same level in the distribution chain is determined by horizontal price transmission. It consists of spreading, via impulses, of prices of a given product in different locations. This phenomenon is defined as the spatial transmission of prices [Fackler and Goodwin 2001]. In macroeconomic terms, integration is a process of strengthening cooperation and connecting markets, which is made possible by eliminating economic barriers between these markets. Spatial market integration refers to the flow of price impulses and the existence of relationships between individual markets (price transmission). Market integration describes a situation where two conditions are met, namely: commodity prices in spatially separated markets change in parallel and signals and information are transmitted fluently between them.

Prices between two markets that trade with each other vary based on the magnitude of the markets’ transaction costs and, in the case of markets between which there is no trade, these differences in prices may not be dependent solely on transaction costs [Tomek and Robinson 1981].

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Spatial integration of markets provides an opportunity to create competitive conditions between markets where prices are mainly differentiated by transaction costs [Barrett and Li 2002]. Measuring market integration can become an essential tool in understanding how markets function [Ravallion 1986].

The fruit and vegetable market is an element of the agricultural market. However, it is distinguished by the existence of autonomous local markets, a high level of seasonality, a significant share of small, non-organised producers, and a wide range of products which differ in quality levels. In addition, large fluctuations in the level of prices, both in time and spatial cross-section, are an important feature. This leads to asymmetry in price transmission, and leads to lack of integration. Determining the level of spatial integration of markets will indicate their efficiency and thus make it easier for producers to make decisions about where to sell their products. The aim of this article was to assess the degree of spatial integration of wholesale fruit and vegetable markets in Poland on the example of carrot, in which Poland is a significant producer.

Wholesale markets play an important role in wholesale trade, which is the link between producers and retailers [Urban and Olszańska 2015]. One of the most important functions of wholesale markets is the price formation through the interaction of supply and demand forces. These markets and their operators are seen as an important element of trade in the agricultural sector, especially in relation to fruit and vegetables [Gołębiewski and Sobczak 2017]. Wholesale markets in Poland were established in the 1990s. These entities were an alternative to marts that dealt with wholesale trade of agricultural products which dominated the trade between producers and retailers in the first years after the transformation. At the same time, the position of existing entities, i.e. cooperatives, was significantly weakened and eventually their place was taken by new entities specialising in wholesale trade [Chojnacki 1999].

MATERIAL AND METHODS

In order to determine the spatial integration of wholesale markets, we used daily prices of carrots sold at five wholesale markets: Warsaw Agricultural-Food Wholesale Market and Wielkopolska Agro-Horticultural Guild S.A. in Poznań, Sandomierz Horticultura Wholesale Market S.A., Agricultural-Food Wholesale Market Giedla Kaliska Sp. z o.o., Agricultural-Food Wholesale Market in Radom and Sandomierski Horticultural Wholesale Market S.A. The time period of the analysed prices (2011–2016) allowed minimising the impact of extraordinary changes in the supply of this commodity. Data on the price levels of carrots selected fruit and vegetable species were obtained directly from wholesale markets and the Polish Wholesale Markets Association.

In order to examine the stationarity of the time series for selecting the appropriate modelling methodology we have used an augmented Dickey–Fuller (ADF) test. The test (ADF) is based on a regression equation [Maddala 2008]:

\[
\Delta y_t = \delta y_{t-1} + \sum_{i=1}^{k} \gamma_i \Delta y_{t-i} + \beta t + \epsilon_t
\]

where:
- \(\delta, \beta, \gamma\) – structural parameters estimated using the least squares method;
- \(k\) – number of lags;
- \(t\) – deterministic trend;
- \(\Delta y_{t-1}\) – the first differences of variable \(y\) in period \(t-1\);
- \(\epsilon_t\) – residuals.

The null hypothesis for this test states that the \(y_t\) series is non-stationary (\(y_t\) has a unit root), while the alternative hypothesis states that the \(y_t\) series is stationary.

The type of process generating \(y_t\) has been also examined on the basis of the autocorrelation function (correlogram), which is in the form of [Box and Jenkins 1970]:

\[
r_k = \hat{\rho}_k = \frac{\sum_{t=k+1}^{T} (x_t - \bar{x})(x_{t-k} - \bar{x})}{\sum_{t=1}^{T} (x_t - \bar{x})^2} = \frac{\sum_{t=k+1}^{T} (x_t - \bar{x})(x_{t-k} - \bar{x})}{T \bar{x}^2}
\]

where:
- \(t\) – time index;
- \(k\) – number of lags;
- \(\bar{x}\) – the average value of \(x\).
In order to analyse the volatility of carrot prices on studied markets and to determine the existence of spatial integration, the structural model VAR (sVAR) was applied:

\[ Bx_t = \Gamma_0 D_t + \Gamma_1 x_{t-1} + \Gamma_2 x_{t-2} + \ldots + \Gamma_k x_{t-k} + \xi_t \]  

(3)

where:

- \( x_t \) – vector of the n variables in the model
  \[ x_t = [x_{1t} \ldots x_{nt}] \]  
  (4)

- \( D_t \) – vector of deterministic components;
- \( \Gamma_0 \) – matrix of parameters for variables in vector \( D_t \);
- \( B \) – parameter matrix when variables of vector \( x_t \) are non-delayed:
  \[
  B = \begin{bmatrix}
    1 & b_{12} & \ldots & b_{1n} \\
    b_{21} & 1 & \ldots & b_{2n} \\
    \vdots & \vdots & \ddots & \vdots \\
    n_1 & b_{n2} & \ldots & 1
  \end{bmatrix}
  \]  
  (5)

- \( \Gamma_i \) (\( i = 1, 2, 3, \ldots, k \)) – parameter matrices with delayed variables;
- \( x_{n}, \xi_t \) – random disturbance vector of the structural model [Kusidel 2000].

The selection of lags was based on the Akaike and Schwarz information criterions.

The Granger causality test was used to analyse relations between the studied variables. Testing causality in the Granger sense is based on the following system of equations:

\[ Y_t = \beta_0 + \sum_{j=1}^{m} \beta_j Y_{t-j} + \sum_{k=1}^{n} \beta_k X_{t-k} + u_t \]  

(6)

\[ X_t = \beta_0 + \sum_{j=1}^{m} \beta_j X_{t-j} + \sum_{k=1}^{n} \beta_k Y_{t-k} + u_t \]  

(7)

where:

- \( Y_t \) – values of the variable \( Y \);
- \( X_t \) – values of the variable \( X \);
- \( \beta \) – structural parameters of the model;
- \( u_t \) – random component of the model [Granger 1969].

The null hypothesis in the Granger Causality test assumes that all \( \beta_k \) coefficients are equal to zero, which means that there is no causality, while the alternative hypothesis assumes the occurrence of causality in the Granger sense.

RESULT AND EMPIRICAL RESEARCH

This empirical study requires examining the stationarity of time series. The test results for the analysed time series are presented in Table 1. The calculated value of ADF test statistics is less than the critical value at each level of significance. Therefore, the null hypothesis about the non-stationarity of the time series for the examined carrot markets should be rejected.

For the time series investigated, autocorrelation and partial autocorrelation functions were generated. The generated autocorrelation functions have confirmed the stationarity of the carrot price series for selected wholesale markets. In this case, autocorrelation functions are expiring systematically and do not take on a sinusoidal shape (the figure). Studying the shape of the autocorrelation function is considered one of the non-formalised methods of testing the stationarity of time series [Kusidel 2000].

In the sVAR model, restrictions were imposed on pairs of parameters corresponding to wholesale

### Table 1. Results of stationarity tests of time series of the examined prices of carrots

| Wholesale market | ADF test statistics | The critical value for a p level of significance |
|------------------|---------------------|-----------------------------------------------|
|                  |                     | \( p = 0.01 \) | \( p = 0.05 \) |
| Bronisz          | -3.221              | -2.568           | -2.863           |
| Poznań           | -3.313              | -2.568           | -2.863           |
| Kalisz           | -3.169              | -2.568           | -2.863           |
| Radom            | -3.629              | -2.568           | -2.863           |
| Sandomierz       | -4.108              | -2.568           | -2.863           |

Source: Calculations and author’s elaboration using the EViews program.
Fig. The autocorrelation and partial autocorrelation functions for examined time series

Source: Calculations and author’s elaboration using the EViews program.
Fig. – cont.
markets with an insignificant exchange of goods. The estimated parameters of the sVAR model indicated the existence of carrot prices integration between all wholesale markets specified in the econometric model (Table 2). Most of the parameters of the sVAR model were statistically significant indicating that price changes in individual wholesale markets may not be independent (although this issue in VAR models cannot be considered on the basis of the t-Student test alone). Results of the estimation of parameters of the sVAR model showed that the price changes in the examined wholesale markets have positive correlation (for all statistically significant parameters). The exception was the dependency between carrot prices in Sandomierz and Poznań. It was observed that changes in carrot prices on a one of these markets are most sensitive to time delayed price changes occurring on the same market (Table 2). On the other hand, carrot price changes recorded on spatially remote wholesale markets show a significantly lower impact on the level of carrot prices on a particular wholesale market. The results of the estimated sVAR model suggest that the volatility of carrot prices on the examined wholesale markets may be subject to spatial dependencies (price transmission) and autoregressive dependencies (the impact of historical prices on a particular wholesale market on its current value). As mentioned previously, the t-Student statistic is not a reliable test for statistical significance of parameter estimates in VAR and sVAR models. Thus, further testing using the Granger causality test was conducted.

Table 2. The parameters sVAR model estimates

| Breakdown     | Bronisz  | Poznań  | Kalisz  | Radom   | Sandomierz |
|---------------|----------|---------|---------|---------|------------|
| Bronisz (–1)  | 0.963058 | 0.000901| 0.077695| 0.088304| 0.018879   |
|               | (0.00819)| (0.00777)| (0.01720)| (0.01645)| (0.01087)  |
|               | [117.604]| [0.11598]| [4.5161] | [5.3687] | [1.7370]   |
| Poznań (–1)   | 0.010626 | 0.954720| 0.061378| 0.082486| 0.028025   |
|               | (0.00781)| (0.00701)| (0.01640)| (0.01485)| (0.01037)  |
|               | [1.36072]| [136.200]| [3.74183]| [5.55557]| [2.70182]  |
| Kalisz (–1)   | 0.021183 | 0.021860| 0.819543| 0.036165| 0.014687   |
|               | (0.00757)| (0.00734)| (0.01590)| (0.01554)| (0.01004)  |
|               | [2.79896]| [2.97990]| [51.5425]| [2.32748]| [1.46270]  |
| Radom (–1)    | 0.008179 | 0.025491| 0.043700| 0.807311| –0.005437  |
|               | (0.00770)| (0.00746)| (0.01617)| (0.01580)| (0.01021)  |
|               | [1.06271]| [3.41757]| [2.70251]| [51.0999]| [–0.53243] |
| Sandomierz (–1)| −0.011941| 0.000000| −0.009901| 0.000000| 0.931445   |
|               | (0.00635)| –       | (0.01333)| –       | (0.00850)  |
|               | [–1.87905]| –       | [–0.74263]| –       | [109.607]  |

Small approximation errors are displayed on grey background; standard deviation of results of t-Student statistics’ are given in square brackets.

Source: Calculations and author’s elaboration using the EViews program.
formation. Results of the Granger causality tests for carrot prices (Table 3) show the interaction of prices in most of the examined wholesale markets. Only in cases of the Warsaw Agricultural-Food Wholesale Market and Wielkopolska Agro-Horticultural Guild S.A. in Poznań, there was no dependency between carrot prices on these markets in 2011–2016.

**Table 3.** Granger causality test results for carrot

| Wholesale market | Bronisze | Poznań | Kalisz | Radom | Sandomierz |
|------------------|----------|--------|--------|-------|------------|
| Bronisze         |          |        |        |       |            |
| Poznań           | (0.1049) |        | (6.E-08) | (1.E-17) | (0.0002) |
|                  | (0.1976) | (9.E-07) | (0.0009) | X     |            |
|                  | X        |        |        |       |            |
|                  | (0.1976) | (1.E-08) | (6.E-08) | (0.021) |            |
|                  | X        | (0.1445) | (0.0184) | X     |            |
|                  |          | X      |        |       | (0.955)    |
| Poznań           | (0.1049) |        | (4.E-05) | (0.0028) | (0.955)    |
|                  |          |        |        |       |            |
| Kalisz           | (9.E-07) | (4.E-05) | (2.E-08) | (5.E-06) |            |
|                  | X        |        |        |       | X          |
|                  | (6.E-08) | (0.1445) | (0.0002) | (0.5105) |            |
|                  |          |        |        |       |            |
| Radom            | (0.0009) | (0.0028) | (0.0002) | (0.0003) |            |
|                  |          |        |        |       |            |
|                  | (1.E-17) | (0.0184) | (2.E-08) | (0.7109) |            |
|                  | X        |        |        |       |            |
|                  |          |        |        |       |            |
| Sandomierz       | (0.8528) | (0.955) | (0.5005) | (0.7109) |            |
|                  | X        |        |        |       |            |
|                  | (0.0002) | (0.955) | (0.5105) | (0.7109) |            |

*p*-value for the relevant test statistic, indicating acceptance or rejection of the null hypothesis for the Granger causality test are given in brackets; X means no causality in the Granger sense; ←, → show directions of causality in the Granger sense.

Source: Calculations and author’s elaboration using the EViews program.

**CONCLUSIONS**

The research based on dynamic econometric methods has shown that there are dependencies in the studied wholesale markets for carrot prices. This indicates the existence of price transmission between the analysed markets, thus suggesting that the analysed wholesale carrot markets were spatially integrated. This research indicates that the largest Warsaw Agro-Food Wholesale Market S.A. in Bronisze influences the formation of carrot prices on all wholesale markets examined, with the exception of the Poznań market (Table 3). At the same time, it was stated that Sandomierz Horticultura Wholesale Market S.A. has the lowest degree of integration with other mentioned wholesale markets. In most cases it is only a “recipient” of carrot price information from other wholesales markets. Moreover, the results of the sVAR model estimation indicate that the changes in carrot prices on a particular market are stronger influenced by the price changes from the same market (autoregressive effect). It also means that the carrot price information coming from other wholesale markets (price transmission effect) has a much weaker effect.
REFERENCES

Barrett C.B., Li J. (2002). Distinguishing between equilibrium and integration in spatial price analysis. American Journal of Agricultural Economics, 84, 292–307.

Box, G.E.P., Jenkins, G.M. (1970). Time series analysis: Forecasting and control. Holden-Day, San Francisco.

Chojnacki, P. (1999). Kształtowanie się zorganizowanego handlu hurtowego na rynku rolno-ogrodniczym. [In:] E. Czernyszewicz (Ed.), II Ogólnopolska Konferencja Ogrodnicza-Ekonomiczne problemy krajowego ogrodnictwa i sposoby ich rozwiązania przed przystąpieniem Polski do Unii Europejskiej. LaserGraf, Lublin, 320.

Fackler, P.L., Goodwin, B.K. (2001). Spatial price analysis. [In:] K. Arrow, M.D. Intriligator (Eds.). Handbook of Agricultural Economics. Vol. 1b. North-Holland, Amsterdam.

Gołębiowski, J., Sobczak, W. (2017). Rynki hurtowe owoców i warzyw. Wydawnictwo SGGW, Warszawa.

Granger, C.W.J. (1969). Investigating Causal Relations by Econometric Models and Cross-spectral Methods. Econometrica, (37) 3, 424–438.

Hamulczuk, M., Gędek, S., Klimkowski, C., Stańko, S. (2012). Prognozowanie cen surowców rolnych na podstawie zależności przyczynowych. IERiGŻ-PIB, Warszawa.

Kusideł, E. (2000). Modele wektorowo-autoregresyjne VAR. Metodologia i zastosowanie. [In:] B. Suchek (Ed.), Dane panelowe i modelowanie wielowymiarowe w badaniach ekonomicznych. Vol. 3. Wydawnictwo Absolwent, Łódź.

Maddala, G.S. (2008). Ekonometria. Wydawnictwo PWN, Warszawa.

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

Tomek, W.G., Robinson, K.L. (1981). Agricultural product prices. Cornell University Press, New York.

Urban, S., Olszańska, A. (2015). Ekonomika handlu żywnością i produktami rolnymi. Wydawnictwo Uniwersytetu Ekonomicznego we Wrocławiu, Wrocław.

INTEGRACJA PRZESTRZENNA RYNKÓW HURTOWYCH WARZYW W POLSCE NA WYBRANYM PRZYKŁADZIE

STRESZCZENIE

W artykule podjęto próbę weryfikacji zjawiska występowania transmisji cen między rynkami hurtowymi w Polsce na rynku marchwi. Okreslenie poziomu przestrzennej integracji rynków wskaże ich efektywność, a tym samym może ułatwić producentom podejmowanie decyzji o tym, gdzie sprzedawać swoje produkty. Dane empiryczne obejmują dzienne notowania cen marchwi na rynkach hurtowych owoców i warzyw w Broniszach, Kaliszu, Poznaniu, Radomiu i Sandomierzu. Zakres czasowy badań obejmował lata 2011–2016. Do analizy wykorzystano metody ekonometrii dynamicznej (model sVAR) oraz przeprowadzono testy przyczynowościi Grangera. Badania przeprowadzone z wykorzystaniem dynamicznych metod ekonometrycznych wykazały, że pomimo występowania istotnych różnic w poziomie cen marchwi na badanych rynkach zaobserwowano ich wzajemne oddziaływania. Ponadto wyniki oceny modelu sVAR wskazują, że na zmiany cen marchwi na danym rynku silniej wpływają zmiany cen z tego samego rynku (efekt autoregresyjny). Oznacza to również, że informacje o cenie marchwi pochodzące z innych rynków hurtowych (efekt transmisji ceny) mają znacznie słabszy efekt.

Słowa kluczowe: transmisja cen, model sVAR, test przyczynowości Grangera, rynki hurtowe, ceny warzyw