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Assesment of advancement level of logistic systems in Polish agri-food industry

Oszacowanie poziomu zaawansowania systemów logistycznych w polskim przemyśle spożywczym

Abstract. The paper presents the results of research on the relationship between the level of advancement of technology, solutions and logistics systems used in the Polish food sector, and the size of employment, scale of investment, financial situation and position on the market of food enterprises. Several different dependency assessment methods were used and compared in the study. The research falls within the broader thematic area of Solow's productivity paradox in its extended understanding of logistics systems [Jałowiecki 2018]. The results obtained seem to correspond to one of the most frequently raised reasons for the occurrence of this paradox related to statistical methods. The main purpose of the research, the results of which were presented in the work, was to construct a synthetic indicator to assess the level of sophistication of logistic solutions used and to use it in the research of the food sector.

Key words: logistic systems advancement, Solow's productivity paradox, synthetic indicator, food industry

Synopsis. W pracy przedstawiono wyniki badań dotyczących związku między poziomem zaawansowania technologii, rozwiązań i systemów logistycznych stosowanych w polskim sektorze spożywczym a wielkością zatrudnienia, skalą inwestycji, sytuacją finansową i pozycją na rynku przedsiębiorstw spożywczych. W badaniu wykorzystano i porównano kilka różnych metod oceny zależności. Badania mieszczą się w szerszym obszarze tematycznym paradoksu produktywności Solowa w jego rozszerzonym zrozumieniu systemów logistycznych [Jałowiecki 2018]. Uzyskane wyniki wydają się odpowiadać jednej z najczęściej podnoszonych przyczyn występowania tego paradoksu związanej z metodami statystycznymi.

Słowa kluczowe: zaawansowanie systemów logistycznych, paradoks produktywności Solowa, wskaźnik syntetyczny, przemysł spożywczy

Introduction

Agriculture and food production has always played a significant role in the Polish economy. As a consequence, Poland has been and still is perceived as a largely agricultural country as well as an important food producer [Borkowski 2003]. Therefore, the agri-food processing sector plays a very important role in the Polish economy. Over the past 25 years, he has undergone significant changes that have completely changed his face. First, in the 90s of the last century, they were associated with the social and political transformation, as a result of which the Polish economy transformed from centrally managed to free market. At that time, changes in the agri-food processing sector concerned mainly the ownership and organizational structure of enterprises as a result of privatization processes and foreign investments. Then, as a consequence of Poland's efforts to join the EU, both before and after accession, changes in the agri-food processing sector covered the organization and technology of food production. They were, in turn, a consequence of the need to adapt Polish food producers to EU legal regulations and quality standards [Krajewski and Borkowski 2002].

The agri-food processing sector includes producers of foodstuffs for humans and animals, non-alcoholic and alcoholic beverages as well as tobacco products. According to the Polish Classification of Activities, the 2007 version (PKD 2007) includes sections C (manufacturing), divisions 10 (production of food products), 11 (production of beverages) and 12 (production of tobacco products). This term, however, does not apply to entities involved in the production of agricultural produce, animal husbandry (section A, division 1), acquisition of wild-growing forest products (section A, division 2), fisheries, fisheries (section A, division 3) and food distribution (section G, chapter 46).

The agri-food processing sector defined in this way covers a very wide and diverse area of production activity. His enterprises can be divided into four types of processing, and then a more detailed division into 11 industries. Enterprises processing animal products include the following industries: meat processing and preserving and production of meat products (group 10.1 according to PKD 2007), processing and preserving of fish, crustaceans, and molluscs (group 10.2) and production of dairy products (group 10.5). Enterprises processing plant products include the following industries: processing and preserving fruit and vegetables (group 10.3), production of grain mill products, starch and starch products (group 10.6). Enterprises dealing with secondary processing include the following sectors: production of bakery and flour products (group 10.7), production of other food products (group 10.8), production of ready feed and animal feed (group 10.9). Only the production of stimulants is involved in the tobacco industry only (group 11.0). There are also industries grouping enterprises dealing with various types of processing: production of oils and fats of vegetable and animal origin (group 10.4) and production of beverages (group 12.0), among which alcoholic beverages are classified as stimulants.

As can be seen, the food processing sector in Poland is very diverse both in terms of industry and due to the very large number of enterprises belonging to the SME segment (small and medium enterprises). The second source of high diversity of the food sector is the large variety of food products resulting from their degree of processing and the complexity of technological processes used in their production. The large dispersion and complex structure of recipients of finished food products also have a significant impact on the increase in the complexity of food products, but above all the complexity of multidimensional logistic networks of food enterprises (see Table 1). Transactions of agri-food products carried out with a retail store will be significantly different from transactions

Table 1. Average numbers of suppliers of agricultural raw materials, recipients of food products and offered assortment items in Polish food enterprises, taking into account the division by industry and according to the size of employment

Tabela 1. Średnia liczba dostawców surowców rolnych, odbiorców produktów spożywczych i oferowanych pozycji asortymentowych w polskich przedsiębiorstwach spożywczych, z uwzględnieniem podziału według branż i grup wielkości zatrudnienia

Group of enterprises	Average number of suppliers	Average number of recipients	Average number of items in the assortment
Meat	255.8	78.8	134.6
Fruits and vegetables	114.5	86.6	99.7
Oil and fats	22.0	10.6	4.6
Dairy	440.9	1375.1	48.4
Cereal and starch	80.6	110.6	54.8
Bakery	8.0	71.4	82.4
Grocery	17.7	145.5	212.8
Feed	51.0	82.4	122.9
Beverages	12.5	183.1	32.9
Micro	23.6	43.9	40.3
Small	40.0	64.4	84.0
Middle	317.3	154.1	155.7
Large	277.6	1396.2	222.1
All	97.8	137.4	**102.0**

Source: [Jałowiecki 2016].

with a commercial network or wholesaler. These differences will concern not only the place and time of loading, or the current quality of the product, but also the range, volume and financial conditions of delivery, and above all the logistics necessary for their implementation. The standardization of transactions in food products is quite difficult in practice, even at the level of prices, which for the same product, but differing in the date of production by a few days can be very different. All this is a significant impediment, e.g. to the digital description of food transactions, or to carry them out via the Internet [Klepacki 2016].

Random factors, such as weather changes, refrigeration equipment failures, and transport delays are other factors that have a strong impact on increasing the complexity of food logistics chains. They all also reduce the level of predictability of logistics processes and lower predictability of prices of agri-food processing products. Geographic and seasonal factors associated with the seasons also have a significant impact on food prices. Their abrupt changes, often have a strong impact on all participants of the food logistics chains.

These conditions make it crucial for food companies to have an effective logistics system. It can be said without exaggeration that proper organization and management of logistics is not only a means to achieve higher competitiveness or greater efficiency of business operations, but above all becomes a condition for functioning on the food market in general [Szymanowski 2008].

The first goal of the research was to develop a synthetic indicator for assessing the level of technology advancement, logistics solutions, and systems in enterprises, and to use it in relation to the food sector. The second objective of the study was to assess the diversity of logistics advancement levels in the surveyed food enterprises, taking into account their breakdown by industry and employment size group, investment level, financial situation, and market position. An additional third methodical goal of the research was to compare two methods of categorizing the value of the synthetic indicator used to assess the level of sophistication of the logistic solutions used: even distribution and division in relation to the average value and fold standard deviation.

It should be also emphasized that in the known literature on the subject, synthetic indicators have not been used so far to assess the level of sophistication of the logistic solutions used. However, the way of constructing analogous indicators for measurements in other thematic areas is quite similar. In connection with the above, experience from the creation of synthetic indicators used in other areas of research related to management and economics was used [Vilaseca et al. 2006, Domínguez-Domínguez and Núńez-Velázquez 2007, Dominiak et al. 2016, Edquist et al. 2018].

Data source and methods

In this research, the REGON database prepared by the Central Statistical Office was used. It was used to obtain the address data of Polish agri-food processing enterprises to which the survey was addressed in the paper version. Also, the survey was made available in electronic form on a website.

The research sample consisted of 512 enterprises in the Polish food sector. In the first stage of research, the results of surveys carried out in these enterprises were used. The surveys, in addition to general information about the surveyed enterprises, provided data on the solutions they use in five areas of logistics: inventory management, warehouse management, transport management, packaging management and reverse logistics as well as organization and management of logistics. They also contained data on information management solutions. In addition to information on solutions, the results of surveys also included assessments of the financial situation, market position, scale of investment processes, costs of logistics activities, knowledge about logistics and the quality of logistics support by ICT.

From among 11 food industry sectors, 9 were selected for further analysis, for which the questionnaires received a sufficient number of responses. For this reason, the research on the industry of processing and preserving fish and other fisheries products (code 10.2 according to the PKD 2007 register) and tobacco production (code 12.0) was abandoned. The surveyed enterprises were divided into 4 groups of employment size according to the methodology used by the Central Statistical Office (GUS). In this way, micro-enterprises (employing up to 9 people), small enterprises (10–49 people), medium-sized enterprises (50–249 people) and large enterprises (250 and more people) were distinguished.

A dedicated synthetic indicator developed based on data from surveys was used to assess the level of advancement of logistics systems used in the surveyed enterprises. The Logistics Advancement Level (LAI) indicator was built in three stages, and then its value was determined for all surveyed enterprises. In the first stage, a set of variables that could potentially affect the enterprise characteristics described by the indicator was selected. The division of variables according to 5 areas of logistics activities: logistics organization, inventory management, warehouse management, packaging, and returnable logistics and transport management. During the selection of potential variables, extensive literature studies and an expert method were used, but it was not possible to refer to existing, similar logistic indicators due to their lack in the literature on the subject. In the second stage, variables strongly correlated with each other within each identified area of logistics activities were eliminated. Then, using the backward stepwise regression method, those variables were eliminated whose impact on the studied enterprise logistics advancement was statistically insignificant. During the aggregation of the values of the left variables into partial indicators for each of the five logistics areas listed, we decided not to assign weights to all components as a weight equal to 1. The reason was the inability to use the expert method and large differences in the ranges of values of individual variables, which in turn did not allow apply statistical weight selection methods, e.g. based on the values of the classic coefficient of variation. The obtained values of partial indices were normalized, and then they were aggregated into the LAI indicator. Finally, the LAI indicator was formed by aggregation of 24 components (Table 2).

Table 2. Components of the synthetic level indicator of logistics solutions (LAI)
Tabela 2. Składniki syntetycznego wskaźnika poziomu rozwiązań logistycznych (WZL)

Area of logistics activities	Components of the LAI indicator
Logistics organization and management	(1) owning a separate logistics department; (2) the number of active areas of logistics; (3) the number of separate cost accounts for various logistics activities; (4) the number of ways to measure service quality and customer satisfaction.
Inventory management	(1) classifying storage; (2) inventory accounting method; (3) method of determining the safety stock of production materials; (4) method of determining the safety stock of finished products; (5) production method taking into account demand and supply.
Warehouse management	(1) the number of collateral in warehouses; (2) sufficiency of storage space; (3) sufficiency of warehouse equipment; (4) method of identifying materials and goods in warehouses.
The management of packaging and reverse logistics	(1) share of packaging and returnable resources; (2) packaging standardization level.
Transport management	(1) transport planning method; (2) use of special vehicles; (3) number of categories of internal transport; (4) the number of categories of external transport and transport services.

Source: [Jałowiecki and Jałowiecka 2014].

In the study, the categorized values of the LAI indicator were used, because the other variables used also had a categorized form. Two categorization methods were used in the study. The first categorization method (method A on the figures) was based on the mean value and standard deviation of the LAI indicator according to the formulas (1). The second method of categorization (method B on the figures) was based on an even division of the entire range of LAI values according to formulas (2).

$$\begin{array}{ll} \text{very low} = 1 & \text{for } \min(x) \le x \le \bar{x} - s_x \\ \text{low} = 2 & \text{for } \bar{x} - s_x < x \le \bar{x} - \frac{1}{2} \cdot s_x \\ \text{middle} = 3 & \text{for } \bar{x} + \frac{1}{2} \cdot s_x < x \le \bar{x} + \frac{1}{2} \cdot s_x \\ \text{high} = 4 & \text{for } \bar{x} + \frac{1}{2} \cdot s_x < x \le \bar{x} + s_x \\ \text{very high} = 5 & \text{for } \bar{x} + s_x < x \le \max(x) \end{array} \tag{1}$$

where:
$\bar{x}$ – average value of LAI indicator;
s_x – standard deviation of LAI indicator.

$$\begin{array}{ll} \text{very low} = 1 & \text{for } \min(x) \le x \le \min(x) + \frac{1}{5} \cdot (\max(x) - \min(x)) \\ \text{low} = 2 & \text{for } \frac{1}{5} \cdot (\max(x) - \min(x)) < x \le \frac{2}{5} \cdot (\max(x) - \min(x)) \\ \text{middle} = 3 & \text{for } \frac{2}{5} \cdot (\max(x) - \min(x)) < x \le \frac{3}{5} \cdot (\max(x) - \min(x)) \\ \text{high} = 4 & \text{for } \frac{3}{5} \cdot (\max(x) - \min(x)) < x \le \frac{4}{5} \cdot (\max(x) - \min(x)) \\ \text{very high} = 5 & \text{for } \frac{4}{5} \cdot (\max(x) - \min(x)) < x \le \max(x) \end{array} \tag{2}$$

In examining the relationship between LAI values and selected characteristics of the surveyed enterprises, a linear regression model was used.

For comparative purposes, another method of identification and assessment of the strength of the relationship between the studied characteristics of food enterprises was also used. It was an independence test based on χ^2 test statistics according to formula (3).

$$\chi^2 = \sum_{i=1}^{k} \sum_{j=1}^{l} \frac{(ni_j - \hat{n}_{ij})^2}{\hat{n}_{ij}} \tag{3}$$

where:
i – number of categories of the first characteristic examined, e.g. employment size;
j – number of categories of the second characteristic examined, e.g. employment size;
n_{ij} – subgroup size in the multi-division table for row i and column j;
$\hat{n}_{ij}$ – theoretical size of the subgroup in the multi-division table in row i and column j.

This method was used only for comparative purposes, because even in connection with the determination of one of the convergence coefficients, e.g. V-Cramer (V_{xy}), T-Czuprow (T_{xy}), it only allows to determine the existence or not dependence, assess its strength, but does not allow to determine its direction (positive, negative).

All calculations were performed at a significance level of α = 0.05. In the case of the chi-square test of independence, the number of degrees of freedom necessary to determine the theoretical value of test statistics was $df = (5 – 1)\cdot(4– 1) = 12$.

Results

The average LAI value obtained when categorizing enterprises according to method A was 3.00, while when categorizing according to method B it was 2.80. Figure 1 shows the average LAI values determined following method A (dark color) and method B (light color) for the food industry sectors under study. The average difference between the LAI values for all food industries was determined as the weighted arithmetic average, in which the number of surveyed enterprises in individual industries played the role of weights. It amounted to 0.206 for the industry and it was the largest for enterprises from the grocery sector (0.733, i.e. 356.7% of the average). The average difference between the average LAI values obtained using the A and B categorization methods (0.206) is slightly larger than the difference between the LAI values obtained for the entire food sector (0.200) using the same categorization methods.

The obtained results, despite quite large differences in the average LAI value in some food industries (other food, dairy and bakery products), indicate some regularity. As for industries, there is no logical order according to which they can be ordered to examine the correlation relationship, and in turn, the use of the chi-square independence test is impossible due to the inability to re-categorize LAI average values, it was decided to use the following scheme tests to determine whether or not this regularity. The average LAI

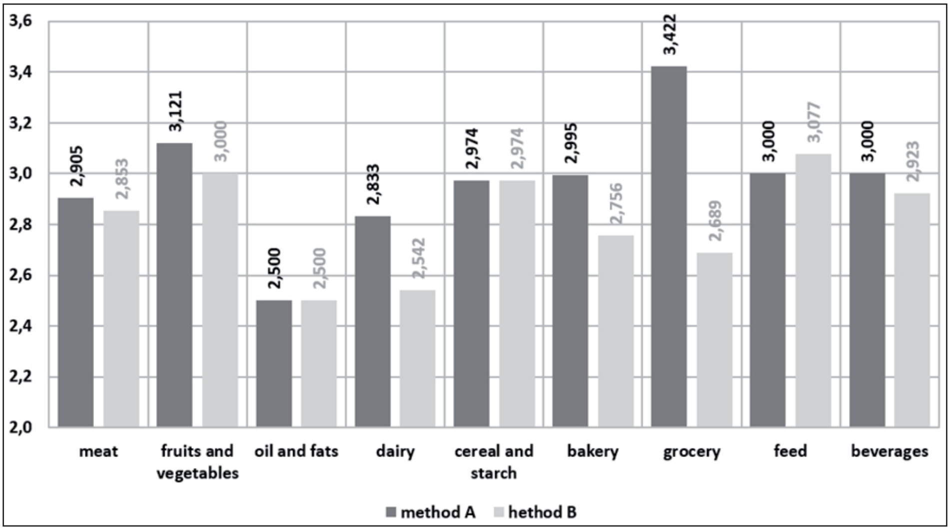

Figure 1. Average LAI values in the analysed food industry sectors in Poland

Rysunek 1. Średnie wartości WZL w badanych sektorach przemysłu spożywczego w Polsce

Source: own study.

values for individual food industries were sorted in descending order, determining their artificial order, and then the values of Pearson's linear (r_P) and Spearman rank correlation coefficients (r_S) with the average numbers of agricultural raw material suppliers, recipients of ready food products and assortment items in the studied sectors were determined. Correlation indicators were determined in this way for both methods of categorization (A and B) and determining the average value of LAI indicators for individual industries.

In the case of the relationship between the average value of the LAI indicator and the number of suppliers of agricultural raw materials, a weak negative relationship, rather non-linear or no such correlation relationship was found (r_P = –0.217, r_S = –0.360 for categorization of LAI indicator method A, and r_P = –0.289, r_S = 0.083 for method B). In the case of the relationship between the average LAI value and the number of recipients of finished food products, the indications regarding the correlation relationship were ambiguous (r_P = –0.136, r_S = 0.301 for method A, and r_P = –0.454, r_S = 0.067 for method B). However, in relation to the relationship between the average LAI value and the average number of product items offered in individual industries, a very strong positive linear relationship was identified (r_P = 0.806, r_S = 0.577 for method A, and r_P = 0.229, r_S = 0.333 for method B).

Figure 2 presents the average LAI values in employment size groups determined following the A and B categorization methods, and the trend lines determined for these methods together with the equations and coefficients of determination R^2.

The results obtained using both methods of LAI categorization indicate two different types of relationships. In both cases, the linear nature of the relationship with similar average strength was found. In the case of method A, this is a negative relationship, which

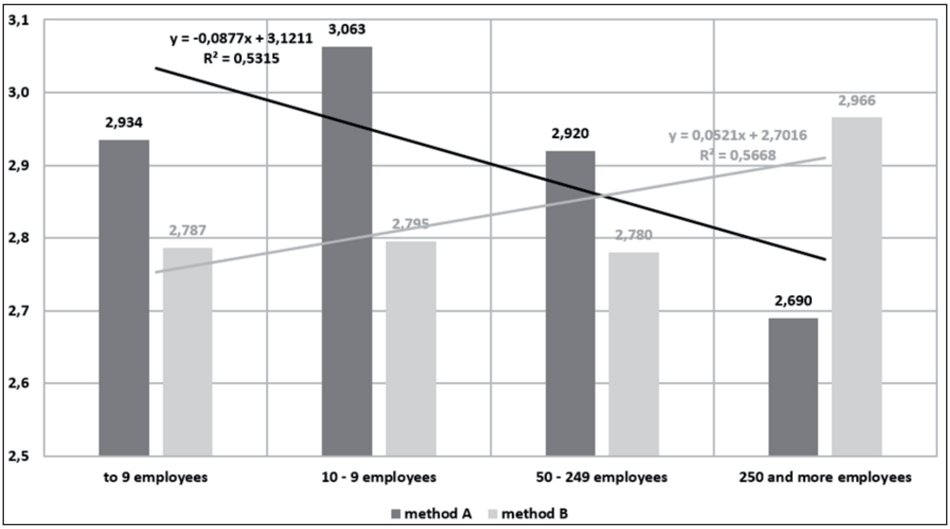

Figure 2. Average LAI values in employment groups in polish agri-food companies

Rysunek 2. Średnie wartości WZL w grupach wielkości zatrudnienia w polskich przedsiębiorstwach rolno-spożywczych

Source: own study.

means that as employment increases, the LAI value describing the advanced level of logistics solutions and systems decreases. In the case of method B, the situation is exactly the opposite, which means that the increase in employment is correlated with the increase in the level of sophistication of logistics solutions and systems. The latter relationship is slightly stronger.

Figure 3 presents the average values of the LAI indicator in individual groups of investment volume of food enterprises determined using the A and B methods of categorizing the value of this indicator and the identified linear trends along with equations and values of the coefficient of determination R^2.

As with employment, the relationships identified using methods A and B are completely different. The positive relationship identified using method B categorization of LAI values is twice as strong as the negative relationship identified using method A.

Figure 4 presents the average LAI values in groups of food enterprises divided according to the assessment of the financial situation using both methods A and B categorization LAI values. As before, linear tendencies with equations and R^2 determination coefficient values were also determined for both methods. This time, the negative relationship identified using Method A categorization of LAI values was about four times stronger than the positive relationship determined using Method B.

Figure 5 presents the average LAI values determined for groups of food enterprises divided according to the market position assessment determined using the A and B categorization methods. Similarly to the assessment of the financial situation, a very strong negative trend meaning that a better market position is not associated with a higher level of advancement of logistics solutions and systems.

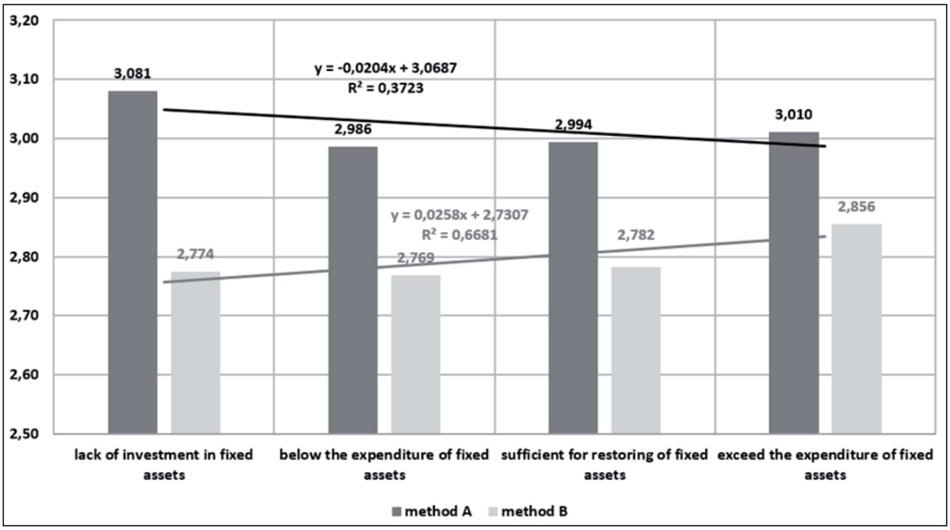

Figure 3. Average LAI values in groups of investment level in polish agri-food companies
Rysunek 3. Średnie wartości WZL w grupach poziomu inwestycji w polskich przedsiębiorstwach rolno-spożywczych

Source: own study.

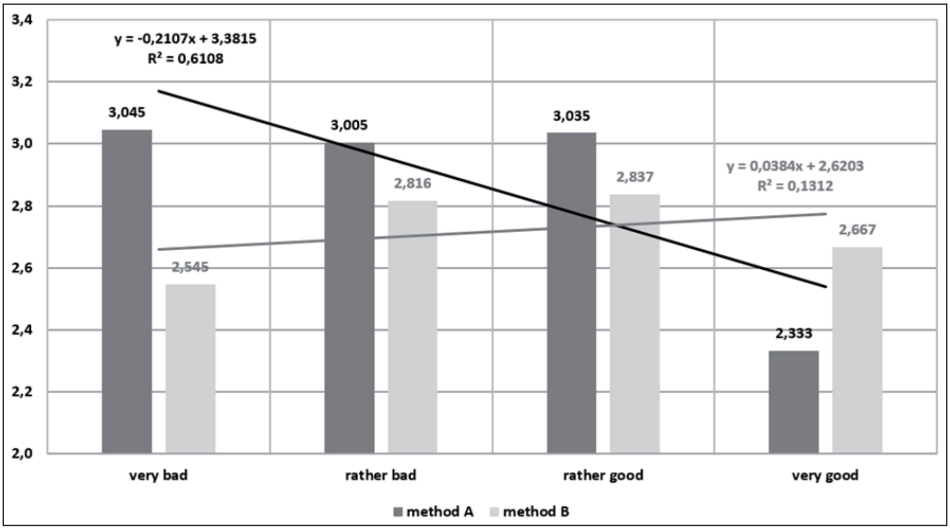

Figure 4. Average LAI values in groups of financial situation level in polish agri-food companies
Rysunek 4. Średnie wartości WZL w grupach poziomu sytuacji finansowej w polskich przedsiębiorstwach rolno-spożywczych
Source: own study.

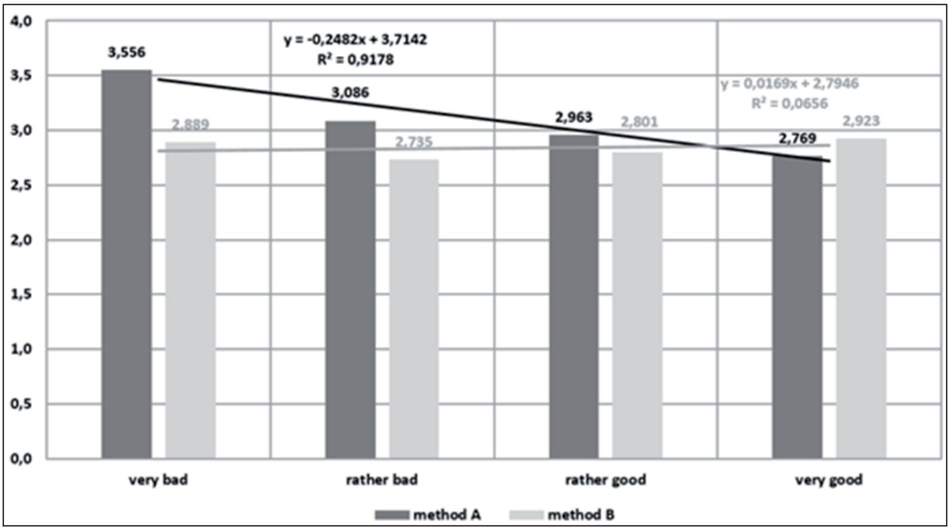

Figure 5. Average LAI values in groups of market position level in polish agri-food companies
Rysunek 5. Średnie wartości LAI w grupach poziomu pozycji rynkowej w polskich przedsiębiorstwach rolno-spożywczych
Source: own study.

In light of the results obtained so far, quite surprising results were obtained by using the chi-square test to identify the relationship between the average LAI value and the studied characteristics of food enterprises. The results for the results of categorization obtained using method A are shown in Table 3, and with using method B in Table 4.

Table 3. Chi-square independence test results for method A
Tabela 3. Wyniki testu niezależności chi-kwadrat dla metody A

Characteristics of enterprises	χ^2	$\chi^2_{\alpha,df}$	p-value	T_{xy}	V_{xy}
Employment size	9.36	21.03	0.67	0.073	0.078
Investments scale	11.76	21.03	0.46	0.086	0.092
Financial situation	10.20	21.03	0.59	0.077	0.083
Postion on market	10.68	21.03	0.56	0.079	0.085

Source: own study.

Table 4. Chi-square independence test results for method B
Tabela 4. Wyniki testu niezależności chi-kwadrat dla metody B

Characteristics of enterprises	χ^2	$\chi^2_{\alpha,df}$	p-value	T_{xy}	V_{xy}
Employment size	11.07	21.03	0.52	0.079	0.085
Investments scale	3.37	21.03	0.89	0.046	0.049
Financial situation	0.43	21.03	0.98	0.016	0.017
Postion on market	8.03	21.03	0.78	0.068	0.074

Source: own study.

According to the results obtained, presented in Tables 3 and 4, no correlation was found between the level of advancement of logistics solutions and systems and employment, the scale of investment, financial situation and market position of the surveyed food enterprises. Additional confirmation of this fact was the extremely low values of the V-Cramer and T-Czuprow convergence indicators, whose values for any dependence and for both methods A and B did not exceed 0.1 (on a scale from 0 to 1).

Summary

The results obtained during the tests are very divergent. Trend analysis using method A of the categorization of LAI index values clearly indicates the occurrence of the Solow productivity paradox. According to the author's previous research in this subject area, the understanding of the Solow paradox should be extended from the traditional area of ICT technologies also to technologies, solutions and logistics systems. This is primarily the result of high synergies between ICT technologies and modern logistics systems known today as e-logistics [Jałowiecki 2018]. In turn, trend analysis using categorization using method B indicates the absence of this paradox in relation to all the characteristics studied, and in the case of employment and investment scale it even indicates a clear positive correlation of these characteristics with the level of advancement of logistics solutions and systems. Finally, as a result of using the χ^2 test of independence, no relationship was found between studied characteristics of agri-food enterprises.

The resulting large discrepancy in results appears to correspond at least in part to one of the most frequently raised reasons for the Solow productivity paradox, using traditional measurement methods that do not take into account many of the intangible aspects of acquiring and implementing ICT, and logistics. First of all, making accurate measurements of the value of investments in information and communication technologies and logistics closely related to them, as well as capital associated with these technologies is very difficult because ICT price indicators take into account only their quantitative changes, but virtually completely omit qualitative changes resulting from the introduction of increasingly modern technology generations.

In general, it should be emphasized that investments in modern ICT technologies primarily create intangible assets that are not in any way taken into account when measuring productivity increases by traditional methods. Such values should undoubtedly include brand value, image, reputation, company reputation, which significantly affect its market position, or intellectual capital (know-how, patents, inventions, future technologies, research and development results), of which measurable the benefits appear in the long term. The implementation of ICT solutions is usually accompanied by complementary investments, especially in the field of organizational and often structural changes in enterprises. This creates a kind of organizational capital, often treated as one of the components of intellectual capital. Although it should undoubtedly be included in assets, it is usually extremely difficult or impossible to estimate its value using commonly used accounting techniques. Finally, all types of statistics do not take into account the so-called “Consumer surplus”, i.e. greater utility for consumers who can more effectively use the producers’ offer. This usefulness is obtained as a result of supporting the possibility of getting acquainted with the range of products and handling transactions by implemented ICT technologies. This type of intangible benefit on the part of the consumer is not only difficult to estimate, in traditional methods of measuring economic growth, the “consumer surplus” is not taken into account at all [Brynjolfsson 1993, Brynjolfsson and Saunders 2010].

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