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Economic Impact of Integration in the Food Supply Chain*

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Abstract

Due to the nature of the food supply chain an important aspect in the context of increasing the efficiency of agri-food companies may be an increase of the integration's degree in the chain. Therefore, exploring the relationships among these variables was found as an important research area and adopted as the goal of the paper. The paper is focused mainly on the theoretical background showing relationship between integration and performance. A description of the theoretical and methodological aspects of performance measurement and its extension (including the integration aspect) was also made in the paper.

For an empirical illustration of the analyzed relationships two steps will be made. Firstly, the integration's degree in the food chain was measured. Secondly, the efficiency of the companies from the cereals processing industry in Europe was assessed. The SFA models (e.g. trans-logarithmic and Cobb-Douglas functional form) were used for assessment of efficiency. By using stochastic method (e.g. the SFA), one may show the influence of external variable (the integration in the supply chain) on the economic performance of enterprises.

Keywords: *integration, food supply chain, economic performance, Stochastic Frontier Analysis*

1. Theoretical background

1.1 Weaknesses of the market

One should begin with the market equilibrium theory, which focal point interaction among market participants is [Kreps 1990]. This interaction is coordinated through the price mechanism – depending on relative prices market, participants (households and enterprises) take individual decisions on supply and demand, so that benefits (or profits) and number of available goods are maximized. The theory passes over analysis of institutional circumstances. However, considering the existence of institutions and organizations makes sense, when the central assumptions of the equilibrium theory are not met, since then one deals with functional weaknesses of the market (i.e. market outcomes are not Pareto-efficient). Elements undermining the market equilibrium theory's assumptions are: information asymmetry and emerging on its basis transaction costs (including property rights and external effects), as well as increasing economies of scale. These elements may cause an incentive for market participants to seek together a solution in a form of institutions or organizations that would compensate functional weaknesses of the market (or eventually

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use them). In this sense, institutions and organizations may be interpreted as a kind of compensation mechanism. Economies of scale, transaction costs, information asymmetry and uncertainty of the transaction may be pointed out as weaknesses of the market indicating the need for integration. In order to reduce the impact of weaknesses of the market or to take advantage of these weaknesses various forms of cooperation between market participants are used. Such unselfish cooperative forms, as presented by Nash basing on game theory, are necessary to achieve the optimal state of the economy [Noga 2009, pp. 67]. These activities are referred to as connections with external partners, integration forms or organizations, outsourcing, hierarchical strengthening within long-term contracts, symbiotic partnerships, cooperation with external partners. These forms are a wide range of intermediate solutions between the market and hierarchy. At the same time, the forms combine elements of the market and hierarchical organization.

1.2 Performance and integration

In the literature one can find arguments indicating that the integration of resources within a single enterprise is more efficient than making transactions through the price system (the market). This is confirmed by A.D. Chandler stating that the internal organizational coordination triggers higher productivity, as well as results in reduced costs and higher profits than coordination by the market [Chandler 1977]. The author continues that what economists call "economies of scale" does not come from an increase in the production volume within one plant, but from use of internal networks between plants within one enterprise and use of internal coordination [Gruszecki 2002, pp. 280].

The aspect of the ownership right plays here an important role. According to A.A. Alchian and H. Demsetz, owners of resources increase their productivity – and thus the efficiency of use of the resources – through cooperative specialization, and this leads to an increase in demand for various types of organizations supporting cooperation [Alchian & Demsetz 1972, pp. 777]. The integration with environment (external organizations) of the system is also highlighted (a company is understood as the system). Cooperation is here the main element of the organizational integration of a company with environment [Steffen & Born 1995, pp. 210 (1987)]. Integration is described both in terms of traditional logistics functions [Gustin et al. 1995] and of removing barriers (or boundaries) between organizations [Naylor et al. 1999]. The need for integration between an enterprise and its environment increases with the degree of intensification of global competition. In this context, the concept of integration, considered as a key factor in achieving better results by an enterprise, is one of the most important topics in the scientific literature.

Analysis of the literature in the field of enterprise's integration with environment enables to show a number of compelling evidence for existence of a relation between integration and productivity, which is acknowledged by M.T. Frohlrich and R. Westbrook; S.K. Vickery, J. Jayaram, C. Droge and R. Calantone [Frohlich & Westbrook 2001; Vickery et al. 2003]. The output of the literature on the integration between partners in the supply chain has significantly increased [van der Vaart and van Donk, 2008]. N. Fabbe-Costes and M. Jahre, in their review of the literature, argue that authors generally agree that stronger relationships and higher integration's degree lead to better business performance [Fabbe-Costes and Jahre 2008].

2. Methodological considerations

2.1 Integration measurement

Some researchers limited their analysis to integration with customers [Closs & Savitskie 2003; Fynes et al. 2005] or with suppliers [Das et al. 2006, Handfield et al. 2009, 2009, Wagner and Krause 2009]. In the literature, there are studies, in which the statement that integration in both directions (upstream and downstream) is more preferable than the integration only with customers or only with suppliers is highlighted. [Frohlich & Westbrook 2001; Rosenzweig et al. 2003]. In some other studies, the authors take a broader perspective when considering the integration of both with customers and with suppliers [Lee et al. 2007] or by defining the integration of the supply chain as an unique concept involving the upstream and downstream integration [Vickery et al. 2003].

Within the framework of the paper a measure of supply chain integration's degree was constructed. The SCIDM (Supply Chain Integration Degree Measure) includes integration with both suppliers and customers. The detailed description will be presented in other paper.

2.2 Production function as a base for performance measurement

It was indicated by Gutenberg that a company (within the meaning of neoclassical theory) can be described by using the production function [see Gutenberg 1965]. The production function is defined by Gutenberg as the base function for analyzing production process [Gutenberg 1968], and it was always considered as a kind of the foundation of theoretical analyzes [Rembisz 2011] in the neoclassical economics. The production function, as a theoretical description of the input(*s*)-output relations, by definition should be treated as a base for enterprises' performance analysis. Thus, the production function is a reflection of the state of technology, including applied technique, organization, knowledge and experience [Bezat at al. 2012].

The SFA method is one of the stochastic approaches that bases on the production function and allows taking into account the statistical noise. The performance-focused modeling presented within the framework of the paper bases on the SFA method (the Stochastic Frontier Approach). The SFA method was applied in the paper because, firstly, it is widely used in research all over the world and, secondly, it is appropriate for samples with high randomness, including agri-food sector. The SFA belongs to the methods that base on the input-output relations function and allow comparing performance (efficiency) of the objects in a sample.

3 Application of the extended SFA method

3.1 Dataset

The efficiency assessment is carried out on the basis of data collected from cereals processing enterprises across Poland within the framework of a scientific project financed by National Science Centre in Poland. The data includes a panel of sheets for the period 2009–2011. The sample covers from 85 up to 87 companies, depending on the analyzed year. The production data is reported as revenue/expenditure denominated in PLN in constant prices. The production frontiers are fitted for a single output and two inputs. The inputs are: value of fixed assets (x_1), operating costs (x_2), and the output is net revenues from sales of goods and materials (y).

3.2 Selection of a functional form and specification of the model

As a parametric approach, the SFA requires assuming a specific functional form determining the input(s)-output relation a priori [Coelli et al. 2005]. Nevertheless, in many cases a model error is likely to occur because the fitted functional form is usually the Cobb-Douglas, which is highly restrictive. The adequacy of the Cobb-Douglas should be tested against a less restricted functional form, which is the trans-logarithmic function [Piesse and Thirtle 2000, pp. 474].

Thus, the study involves two functional forms describing the input(s)-output relations, namely the Cobb-Douglas (equation 1) and trans-logarithmic model (equation 2). The tested frontier models take following form:

$$\ln y_i = \beta_0 + \sum_{j=1}^{k} \beta_j \ln x_{ij} + v_i - u_i \tag{1}$$

and

$$\ln y_i = \beta_0 + \sum_{j=1}^{k} \beta_j \ln x_{ij} + \frac{1}{2} \sum_{j=1}^{k} \sum_{l=1}^{k} \beta_{jl} \ln x_j \ln x_l + v_i - u_i \tag{2}$$

where:

i – index indicating objects i=1,…,I, where I is a number of objects in a sample,

j – index indicating inputs j=1,…,l,

y_i – output of an object i,

x_{ij} – input j of an object i,

β – vector of parameters to be estimated,

v_i – random variable representing the random error, so called statistical noise,

u_i – a positive random variable associated with technical efficiency (TE).

Comparison of the selected functional forms is carried out basing on the likelihood ratio test statistics (LR, Table 1). The LR statistics has the following form:

$$LR = -2[\ln L(R) - \ln L(N)] \tag{3}$$

where:

lnL(R) – logarithm of the maximum likelihood value in the restricted model,

lnL(N) – logarithm of the maximum likelihood value in the non-restricted model.

Table 1. Likelihood ratio statistics and model's selection verification

years	*lnL(R)*	*lnL(N)*	*LR*	result[1]	model
2009	-130,64	-130,97	-0,66**	acceptance of H0	Cobb-Douglas
2010	-118,15	-116,90	2,50**	acceptance of H0	Cobb-Douglas
2011	-126,21	-122,35	7,73**	acceptance of H0	Cobb-Douglas

[1] The value of test statistic for $\chi^2(3)$ distribution amounts 7,82 at the significance level of 0,05 (**) and 11,34 at the significance level 0,1 (*).
Source: own calculations.

The likelihood ratio tests lead to acceptance of the null hypothesis, saying that the Cobb-Douglas (a model with restrictions on parameters) better describes the inputs-output relations (equation 1). Therefore, the empirical results obtained from estimating only the Cobb-Douglas function are reported in the section 3.3.

The output-oriented efficiency ratio – in the case of the stochastic frontier function – is measured as a relation between an observed output (value y, equation 1) and maximum output possible to be achieved in environment characterized by *exp(v_i)* (value *y**). Hence, the ratio may be written as:

$$TE_i = \frac{y_i}{y_i^*} = \frac{\exp(\beta_0 + \sum \beta_1 \ln x_{1i} + \sum \beta_2 \ln x_{2i} + v_i - u_i)}{\exp(\beta_0 + \sum \beta_1 \ln x_{1i} + \sum \beta_2 \ln x_{2i} + v_i)} = \exp(-u_i) \tag{4}$$

On the basis of equation (4) it can be stated that the value of the TE ratio varies from 0 to 1, where the unity indicates that this firm is technically efficient. Otherwise $TE_i<1$ provides a measure of the shortfall of observed output from maximum feasible output in an environment characterized by *exp(v_i)*, and indicates the inefficiency of this firm.

The maximum-likelihood estimates of the parameters in the selected stochastic frontier production functions were calculated (section 3.3).

3.3 Relationship of integration and performance

In the case of the SFA, it is possible to examine the impact of exogenous variables (not included in the adopted function) on the level of the variable u_i [Sellers-Rubio and Mas-Ruiz 2009, pp. 663, Coelli 1996, pp. 7, Battese and Coelli 1995]. It is assumed that u_i is characterized by the limited-normal distribution truncated in zero, average $z_i\delta$ and variance σ_u^2 (according to the approach presented by G.E. Battese and T.J. Coelli [Battese and Coelli 1995, pp. 326]):

$$u_i \sim N^+(z_i\delta, \sigma_u^2) \tag{5}$$

where:

z_i – vector of independent variables associated with inefficiency,

δ – vector of parameters to be estimated.

The variable characterizing the integration's degree of analyzed objects (variable: *SCDIM*) was applied in the model. It should be noted that estimation of the parameters of the vector zi determines the strength of influence of a given variable on increasing the inefficiency level of the analyzed group, thus a negative value of the parameter indicates a positive influence on efficiency and a positive value – a negative influence on efficiency.

The maximum likelihood estimations of the Cobb-Douglas function's parameters are presented in Table 2. All the parameters (*x1*, *x2*, *SCIDM*) are statistically significant at the significant level lower than 0,1.

Table 2. The maximum likelihood estimates of the Cobb-Douglas function's parameters

variables	parameter	Z-2009			Z-2010			Z-2011		
		parameter's value	T-value	p	parameter's value	T-value	p	parameter's value	T-value	p
intercept	b_0	2,88	2,95	***	0,74	0,72		0,74	0,67	
X_1	b_1	0,39	3,11	***	0,54	4,53	***	0,18	2,06	**
X_2	b_2	0,26	1,69	*	0,23	1,68	*	0,55	4,41	***
intercept		3,58	9,21	***	-1,85	-0,16		0,29	0,55	
SCIDM	$\mathbf{b_3}$	**-0,01**	**-2,65**	***	**-0,04**	**-1,95**	*	**-0,04**	**1,74**	*
number of objects		85			87			86		

Signif. codes: 0.01 '***' 0.05 '**' 0.1 '*'
Source: own calculations.

Basing on the value of parameter (b_3) from the model Z-2009, Z-2010 and Z-2011 an influence of integration on performance (efficiency) of the analyzed group can be indicated. The parameter (b_3) takes values from -0,01 (model Z-2009) to -0,04 (model Z-2010 and Z-2011), and the parameter (b_3) is significant at the significance level of 0,05 for models Z-2009 and at the significance level of 0,1 for model Z-2010 and Z-2011. The value of the parameter (b_3) indicates that an increase in integration's degree by one percent determines the decrease in inefficiency by 1% (model Z-2009) and 4% (models Z-2010 and Z-2011), thus the calculated value of the parameter (b_3) indicates the positive influence of integration on the performance (efficiency) of enterprises in the analyzed sample.

In Figure 1 the results presenting the dependence of the efficiency ratios and the integration's degree were visualized and trend functions determining the relationships between the two variables were plotted.

Figure 1. The relationship between the efficiency and the integration's degree for cereals processing companies in the period 2009-2011

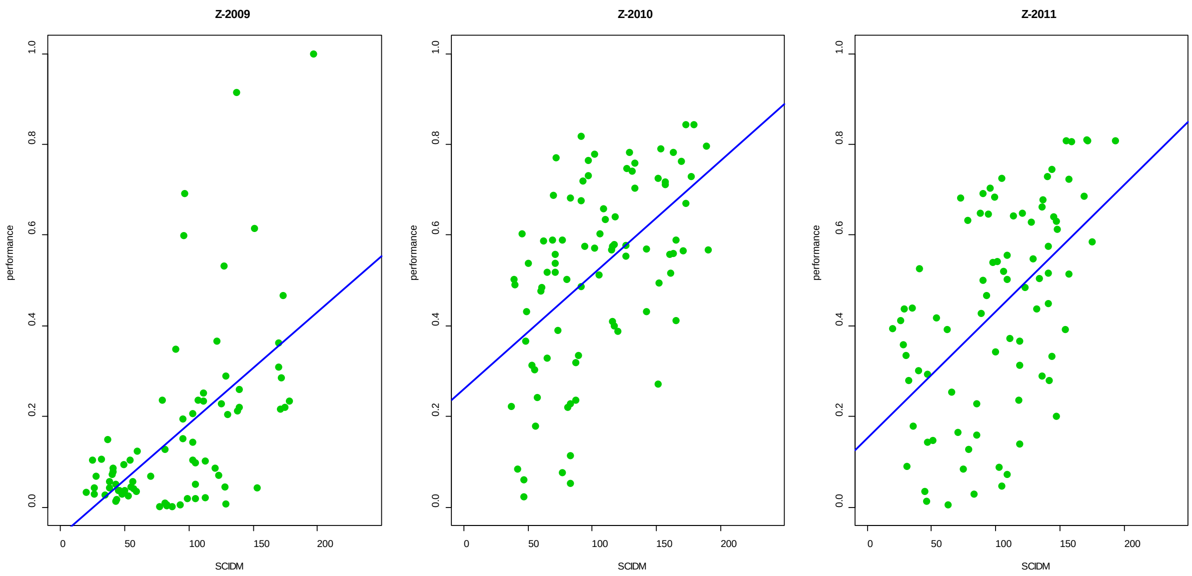

Figure 2. The relationship between the efficiency and the integration's degree for cereals processing companies in the period 2009-2011

Source: own work, the graph generated in the R software [R 2008].

On the basis of analyzes of the functions presented in Figure 1, it was confirmed that the relationship between the performance (efficiency ratios) and the integration's degree is positive in each of the analyzed years. In other words, with an increase in the integration's degree the efficiency ratio increases (Pearson's correlation coefficients for these variables are greater than 0,53 at the significance level of 0,01). The visualization plotted in Figure 1 can be treated as an additional confirmation of the positive relationship between integration's degree and performance (efficiency).

4 Discussion

Within the framework of the paper the theoretical background for relationships between performance and integration was presented. To analyze the relationship the performance-focused modeling based on the extended SFA method was applied for the sample of grain processing companies in Poland. Some theoretical and analytical implications for modeling of relationship between performance and integration were explored in the study as well.

4.1 Theoretical implications

When analyzing the enterprise performance one should keep in mind not only its internal activities but also relationship to the environment. It is obvious that to ensure continuous performance improvement each enterprise should have some kind of symbiotic relations with its suppliers and customers. This aspect of enterprise analysis was shown in the economic literature. Elements like: information asymmetry and emerging on its basis transaction costs (including property rights and external effects), as well as increasing economies of scale undermine the market equilibrium theory’s assumptions and may cause an incentive for market participants to organize collaborative activities. These activities are referred to as connections with external partners in form of integration. One may argue that the cooperative forms are necessary to achieve the optimal state of the economy.

4.2 Analytical implications

As it was shown in the paper the stochastic frontier approach can be a useful tool for estimating the performance on the enterprises. Nevertheless the approach was extended by applying into the models an external variable (not included in the analyzed model). It should be noted that estimation of the parameters of the vector z_i determines the strength of influence of a given variable on increasing the inefficiency level of the analyzed group, thus a negative value of the parameter indicates a positive influence on efficiency.

5 Conclusions

It is clear that there are some theoretical foundations and emerging evidence of a positive relationship between supply chain integration and performance of a company. Nevertheless, D.C.K. Ho, K.F. Au, E. Newton postulated in this context to establish the structures and methods that help to describe and explain the relationship between integration and performance practices of companies in the supply chain [Ho et al. 2002, pp. 4415]. The paper can be treated as a next step made within the framework of the literature discussion on the methodological explanation of the relationship between the integration and performance.

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