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The Measuring the Efficiency of Food Chains – Selected Approaches[1]

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ABSTRACT

The aim adopted in the paper is to review methods for assessing the efficiency of supply chains and to carry out their critical evaluation. Literature studies, interviews, analysis of processes in the chains are used for analyzing of interdependence between the individual stages of supply chain and identifying the efficiency of entire supply chain. An important aspect is to determine the possibility of assessing the efficiency of supply chains in selected sectors of agribusiness by using approaches presented in the paper. Within the analyzed methods, the stochastic frontier approach can be an useful tool for estimating the efficiency on the firm level. However, the efficiency scores obtained from estimation of the stochastic frontier have a little use for policy implications and management purposes if the empirical studies do not investigate the sources of the inefficiency. Thus, it is recommended to include into the models external factors like, for instance, the degree of competitive pressure, the ownership form, various managerial characteristics, network characteristics and production quality indicators of inputs or outputs.

Keywords: *supply chain management; food supply chains; efficiency*

1. Introduction

One assumes that in competitive market equilibrium the price is fixed for producer-processor. In this situation enterprises operating on a competitive market seek possibilities for maximization of expected profit by increasing production. The increase in production contributes to economic growth and thus to the growth of overall economic welfare. But on most of markets in countries with a high GDP per capita (eg. countries of Western Europe or North America) the rate of production growth in a sector is determined by low demand increment.[4] Therefore, the low growth rate of demand must determine the change of efficiency-based relations treated as a main growth factor in the sector. Thus, the Authors believe that not the increase of input factors but the efficiency of its use is the main factor of producers' competitiveness that is expressed by the ability for long-term and effective growth and performance. To sustain long-term growth and profitability in a competitive environment, industrial enterprises must continuously improve their efficiency (Sudit, 1995). The search for potential improvement of efficiency has also been spurred on by the realization that not only does single enterprise compete against each other but also entire supply chains (Christopher, 1992). Taking into account the interactions occurring between the different stages of the supply chain and the structure of activities within and between companies is critical for the efficiency of the entire supply chain. Therefore questions concerning the measurement of efficiency are increasingly important. Methods for process improvements are mostly developed and introduced by practitioners, however many of them use simple techniques rather than analytical methods. The performance measures used in most companies have several problems that prevent them from effectively measuring supply chain performance. Many measures identified as supply chain metrics are actually measures of internal logistics operations such as fill rate, lead time, on-time performance, damage and responsiveness (Gilmour, 1999)

[1] Research granted by National Science Centre from the funds for science in years 2011-2014 as a scientific project no 2011/01/B/HS4/02612 Degree of integration in supply chain and efficiency of food processing enterprises.

[4] Researches confirm that a given growth of demand for agri-food products, occurring at a specific time, determines also the output growth in the agri-food sector (Figiel and Rembisz, 2009).

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and are not the multi-firm measures that are necessary to measure the performance of the supply chain (Beamon, 1989). Therefore there is a strong demand for methods of efficiency assessment and analyzing of benchmarking results, which can be used for design, analysis and improvement of processes in the supply chains. The supply chain must be viewed as one entity and any measurement system should span the entire supply chain (Holberg, 2000). Nevertheless, a review of the literature shows that there are not many applications of the methods for efficiency assessment in the area of supply chain management (Reiner and Hofmann, 2006). More research is needed to develop supply chain metrics and to overcome the implementation barriers (Cooper et al., 1997).

Within the framework of the paper selected approaches of efficiency assessment of supply chains are analyzed and their critical evaluation is carried out (see the section 3.). In addition to the literature studies an interview in form of consultation with Prof. Douglas Lambert (USA) is conducted. As an outcome of the paper the considerations of possibility of assessing the efficiency of supply chains in selected sectors of agribusiness by using approaches presented in the paper are included (see the section 3.).

2. Characteristic of food supply chain

The process of food production, that takes place in each national economy within the framework of its subsystem known as food economy, is the point of reference in the agribusiness chains (Grabowski, 1998). According to A. Zalewski (1989), food economy is among the most important and the most complex segments of the national economy. It covers the whole process of material production associated directly and indirectly with food production and distribution. It consists of manufacturing the means of production for agriculture, agriculture and food industry. According to A. Woś (1998), the concept of the food economy is a term that preceded the development of the theory of agribusiness and was used for the determination of related links of the national economy, which are directly and indirectly involved in food production and distribution.

Food production and distribution are one of the key conditions for functioning of the agribusiness. The way and principles of food movement from the farmer to consumer are determined by agribusiness links that form the food chain. F. Tomczak (2004) states that the food chain provides the food supply from the farm gate to the consumer, transforming agricultural raw materials into products that may be easily purchased, prepared and consumed. The chain includes purchasing, processing, distributing companies as well as food service companies and retail traders, and as a result of the overall transformation and economic needs it is constantly changing and being developed.

Different types of entities may be distinguished within the structure of the food chain (Lazzarini et al., 2001), namely: agriculture, food industry, wholesale and retail trade. In the literature, one can also find other systematics. On the basis of literature review it was stated that the structure characterizing the food supply chains should include agriculture, purchase and trade of agricultural products, food industry, wholesale and retail trade and other entities, such as: government institutions, local government institutions, service providers including providers of means for agricultural production. They are a network of organizations involved, due to relationships with suppliers and customers, in a variety of processes and activities that create value in a form of products and services delivered to final consumer (Rutkowski, 2004). The supply chain with respect to food products can be defined as "cooperation in different functional areas of agricultural producers, intermediary companies (trade), processing companies, manufacturing, services and their customers, between which flow streams of agri-food products, information, and funds" (Jarzębowski and Klepacki, 2013).

The supply chain can be analyzed by the contribution of individual stages while creating added value. Within the framework of the food supply chain, it may be noticed that in the long term the share of agricultural products in consumers' budget shows a continuous downward trend. In this context, the reference to an example of the Dutch market has been made, where more and more value added is generated within the stage of processing, trade and services, and less on the level of agricultural production. This trend intensified in the early nineties. Reducing share of farmers in the overall income of the supply chain need not to be directly related to their performance, which is determined rather by return on investment and labor productivity (Ondersteijn et al., 2006).

The observed phenomenon may be a result of significant changes in food consumption. One can noticed a shift from consumption of fresh products in the direction of processes products and from consumption at homes towards consumption outside homes. Production of processed food requires the involvement of the greater part of value added than in the case of fresh products. This shift in the way of consumption is reflected in food products, in the creation of which processing and trade have the largest

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share. The main problem of modern agriculture is that societies become wealthier, while farmers in these countries are getting poorer. As stated by A. Czyżewski et al. (2006) added value in the market mechanism is distributed in such way that most of the gain goes to those who are closest to the consumer. Market redistributes added value depreciating agriculture, thus the government should step into the sphere of intermodal flows in order to transfer the created and not realized by farmers value added (Kowalski and Rembisz, 2005). Also capital integration of farmers and processing companies may be a mechanism that counteracts the depreciation (e.g. it takes place in milk processing).

The other feature of the food supply chain is a product that is a subject of specific safety requirements designed to protect the final customer (the consumer). Throughout the food supply chain the adequate level of quality, hygiene and wholesomeness for all intermediate and final products should be provided. Wholesomeness of products should be provided at the beginning of the chain, so on farms, including their suppliers of inputs and services (Bezat and Jarzębowski, 2011), through trade and processing (primary and secondary) to the distribution system, including consumer products, as well as final consumers. Thus, a wide variety of standards and rules affects the activities of enterprises in the food chain. Regulations concerning the quality of agricultural products are the important aspect associated with the specificity of food processing. The growing requirements of consumers cause that more and more attention is paid to high quality of these products. At the same time the quality shows a direct relationship with the price of the product and has a direct relationship with the standards (Makarski, 1998).

Furthermore, one of the main elements of food safety is assurance of identifying the origin of the product which was described in the EU Regulations No. 178/2002 or 1935/2004. The regulation 178/2002 was remitted to lay down the general principles and requirements of food law, establishing the European Food Safety Authority and lay down procedures in matters of food safety (Regulation, 2002). The requirement 178/2002 should guarantee the full traceability of food demanding from each stage of supply chain collecting data about products. It obliges companies in the food chain to guarantee the traceability of its products as well as to recall of unsafely products (products recall actions). In this way tracking and tracing of food from the producers to industry and from logistic services to final costumers will be possible (Bezat and Jarzębowski, 2008). The Regulation has shown that food processing companies should implement a system that allows the identification of the product from primary production up to final consumers (tracking) and in the opposite direction (tracing). These companies should also, if necessary, share information about their suppliers and recipients of the relevant services (Regulation, 2002). With the concept of traceability it is possible to indicate where in the chain some problems occurred.

The central condition is the chain-wide coordination of the data exchange and the tracking and tracing of the data which should include quantity, type of raw materials, origin (import, country), supplier information, transport and warehousing information. The linking of defined product unities with the accompanying parameters relevant for product and the access possibilities on the suitable information is the basis of the development of traceability systems (Bezat and Jarzębowski, 2008). This is particularly important in supply chains, in which the cargo handling, transport and processing of raw materials (lots of them) are mix with each other frequently. Defining units and size (Traceable Resource Unit) allows tracking goods, clear differentiating of specific parts and forming new parties arising from the combination of the others.

The implementation of solutions supporting food security covering the entire supply chain is voluntary and depends on the market situation and the structure of companies' customers. However, the recipient may, depending on their market power, influence the quality policy of its suppliers which are forced to provide information about the use of manufacturing technologies and their impact on hygiene and quality of the delivered products. Thus, the assurance of products' wholesomeness is dependent on proper communication with customers and consumers, and creation of the quality tracking systems is a challenge for the entire supply chain.

3. Selected approaches of efficiency assessment of supply chain

The selected approaches of efficiency assessment of supply chains, published in leading Journals dealing with logistics and supply chain management were analyzed. For each approach the methods of efficiency assessment, variable set and sample ware analyzed and criticized (see Table 1).

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Researchers confirm that several performance measures integrated with the best practice processes must be analyzed (Imai and Itami, 1984]. Implementing a supply chain strategy requires metrics that align performance with the objectives of other members of the supply. D. Lambert points out that several factors are contributing to management's need for new types of measures for managing the supply chain including (Kappich, 1989):

- The lack of measures that capture performance across the entire supply chain.
- The requirement to go beyond internal metrics and take a supply chain perspective.
- The need to determine the interrelationship between corporate performance and supply chain performance.
- The complexity of supply chain management.
- The requirement to align activities and share joint performance measurement information to implement strategy that achieves supply chain objectives.
- The desire to expand the "line of sight" within the supply chain.
- The requirement to allocate benefits and burdens resulting from functional shifts with the supply chain.
- The need to differentiate the supply chain to obtain a competitive advantage.
- The goal of encouraging cooperative behavior across corporate functions and across firms in the supply chain.

The aspects mentioned above could be treated as an advice for researchers working on complex methods for efficiency assessment of entire supply chain.

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Tab. 1. Analysis of selected papers on efficiency in the supply chain

Authors, Journal	Methods of efficiency assessment	Variables/Sample	Notes on applied approach	Critics
Reiner G., Hofmann P. (2006), International Journal of Production Research	DEA (Data Envelopment Analysis)	5 from 21 performance measures based on the SCOR model selected by using TRETAD/18 DMU from consumer goods sector (CG)	Small sample size Diversity of results obtained from 3 DEA models applied in the study	No guidelines according specification of the DEA method - variables' selection bases on knowledge of experts, low statistical evidence of the results
Nagurey A., Qiang Q. (2008), Journal of Global Optimization	The Network efficiency measure by Nagurney and Qiang (the N-Q measure)	Cost link functions, demand / Electric power supply chain network	Proposed measure provides more realistic assessments of the performance of critical infrastructure networks as compared to an existing measure (the L-M measure)	No explanation in the paper according creation of cost link function which from economical point of view is of a high importance.
Lambert D. (Ed.) (2008), Supply Chain Management – Processes, Partnership, Performance	Economic Value Added (EVA), Profit and Market Capitalization	The framework consist of seven steps: Map the supply chain, Analyze each link, Develop profit and loss statements, Realign supply chain management processes, Align non-financial with profit and loss, Compare across firms and Replicate / US Industry	The link-by-link approach provides means for aligning performance from point-of-origin to point-of-consumption with the overall objective of maximizing shareholder value for the total supply chain as well as for each company	An advanced, complex approach. Possible problems with access / collection of dataset to assess the performance of several supply chain participant might occur.
Jarzębowski S. (2013), The integration of supply chain as an element of the efficiency development of food processing sector	Supply Chain Integration Degree Measure (*SCIDM*)	Supply Chain Integration Degree Measure includes integration with both suppliers and customers	Three steps procedure: (1) The differentiation of integration direction (downward or upward or both directions); (2) The rang of integration - areas of cooperation. In the next step, the level of integration was analyzed, which can be described as the degree of development of integration activities, respectively in both directions, supplier (ILS) and customers (ILC)	Possible problems with access / collection of detailed dataset to assess the performance might occur.

Source: own work.

Approaches listed in the Table 1 are described in following sections.

Approach of G. Reiner and P. Hofmann

Within the framework of the paper of G. Reiner and P. Hofmann (2006) a composite measure of the total efficiency by using DEA (Data Envelopment Analysis) method to identify the "best practice" chain was proposed. Multiple input and output indicators were included in the analysis. The comparable set of data from different companies was collected on the base of widely accepted industry standard, the Supply Chain Operations Reference (SCOR, 2012). Within the framework of the analysis 18 enterprises from different branches of the consumer goods industry (CG) were included and 7 variables were selected by using TRETAD analysis. One could note that such low number of analyzed objects is unacceptable because of the “curse of dimensionality”, typical to the nonparametric methods (e.g. DEA), that requires increasing a sample in order to eliminate the significant measurement error and imprecise estimates (for example resulting from large confidence interval) (Kneip et al., 1998). However, one should bear in mind that a small sample can cause that a lot of DMUs will be on the frontier, which in consequence will significantly increase the average efficiency ratio (Adler and Golany, 2007). One can observe diversity of results obtained from three DEA models applied in the study. This is so because the efficiency measurements can differ depending on the model specification (input- vs. output-oriented models) and the variable specification (e.g. the degree of aggregation and the units used to measure inputs and outputs). At the same time – in the context of the inability to use statistical tests – choosing the correct model is a matter of expert intuition.

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Approach of A. Nagurney and Q. Qiang

Within the framework of the paper of A. Nagurney and Q. Qiang (2008) network performance/efficiency measure (the N-Q measure) that captures demands, flows, costs, as well as the behavior of users of the network, was demonstrated. This measure can be applied "to assess the efficiency of critical infrastructure networks as well as importance and ranking of network components" (nodes and links). Based on the N-Q measure one can identify which networks components have the greatest impact in terms of their removal and, hence, which are important from both vulnerability as well as security standpoints. The Authors use the concept of network equilibrium to construct the analyzed network, for which it is assumed that sum of path flows must be equal to the demand, flow on a link is equal to the sum of the flows on the paths which contain that link and the user cost on a path is equal to the sum of users costs on links which make up the path. In the approach presented by A. Nagurey and Q. Qiang (2008) the demand's value and user cost link functions are assumed to be given which is quite restrictive because demand and cost might vary at different points of time. In the paper one do not find any explanation according to creation of cost link function which from economical point of view is of a high importance.

Approach of the Global Supply Chain Forum

Despite the complexity and overlap existing in most supply chains, managers can develop metrics to align the performance of key business processes across multiple companies. In the research conducted by the Global Supply Chain Forum in USA a framework that aligns performance at each link (supplier-customer pair) within the supply chain is proposed. The framework begins with the linkages at the focal company and moves outward a link at a time. The link-by-link approach provides means for aligning performance from point-of-origin to point-of-consumption with the overall objective of maximizing shareholder value for the total supply chain as well as for each company. The framework consists of seven steps (Lambert, 2008):

- Map the supply chain from point-of-origin to point-of-consumption to identify where key linkages exist.
- Use the customer relationship management and supplier relationship management processes to analyze each link (customer-supplier pair) and determine where additional value can be created for the supply chain. The authors propose the measurement how customer and supplier relationship management (CRM & SRM) affects Economic Value Added (EVA).
- Develop customer and supplier profit and loss (P&L) statements to assess the effect of the relationship on profitability and shareholder value of the two firms. The authors propose to use a combined customer-supplier profitability analysis. When the customer P&L are aggregated for all customers and corporate joint costs deducted, the results represent overall firm performance.
- Realign supply chain management processes and activities to achieve performance objectives.
- Establish non-financial performance measures that align individual behavior with supply chain management process objectives and financial goals. The authors propose to identify process improvement opportunities. Customer and supplier reports should capture the impact of improved performance in each process.
- Compare shareholder value and market capitalization across firms with supply chain objectives and revise process and performance measures as necessary. This is the final step in the framework and shows how order fulfillment affects Economic Value Added (EVA).
- Replicate steps at each link in the supply chain. By analyzing the processes at each link and understanding the value the link creates, managers can align the supply chain management processes in order to provide the best value for consumers and highest profitability and shareholder value for each company.

Managers should assess whether the process changes and metrics employed have produced the targeted levels of profitability and shareholder value. They may need to refine the processes or make additional trade-offs to achieve the targets.

A single inventory turn metric for the supply chain cannot capture the differences that an improvement in turns will have at each level or for the total supply chain. Performance, as measured by total inventory carrying cost, would be a better measure since it considers both the cash value of the inventory at various positions in the supply chain as well as varying opportunity costs for inventory investments for various supply chain members (Stock and Lambert, 2001). Total inventory carrying cost is improved by pushing

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inventory backwards in the supply chain towards the point of origin. The further it goes back across the supply chain, the lower the overall inventory carrying costs for the entire supply chain. Consequently, inventory turns and other commonly used logistics measures are inadequate for evaluating and aligning performance across multiple companies in the supply chain.

Supply Chain Integration Degree Measure Approach

Within the approach the issue of integration in the supply chain was raised. The Author indicates that efficiency of enterprise can be increased if there is a strong cooperation within the entire chain. 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 and Born, 1995). The 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. The aspect of the ownership right plays here an important role. According to A. Alchian and H. Demsetz (1972), 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. 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 (1977) stating that the internal organizational coordination triggers higher productivity, as well as it results in reduced costs and higher profits than coordination by the market. 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).

Within the framework of the monograph of S. Jarzębowski (2013) a stochastic frontier approach was adapted to assess the efficiency of the supply chain. In the case of the SFA, it is possible to examine the impact of exogenous variables. In the context of this work, a variable showing the cooperation in the chain was included into the model. The supply chain integration's degree was constructed. The SCIDM (Supply Chain Integration Degree Measure) includes integration with both suppliers and customers[5]. The construction of the measure of supply chain integration can be formulated as follows:

$$SCIDM = \sum_{i=1}^{k}\sum_{j=1}^{n} IRS_i \cdot ILS_j + \sum_{i=1}^{k}\sum_{j=1}^{n} IRC_i \cdot ILC_j$$

where:

SCIDM – Supply Chain Integration's Degree Measure,

IRS – Supplier Integration Range,

ILS – Supplier Integration Level,

IRC – Customer Integration Range,

ILC – Customer Integration Level,

i – Areas of cooperation, where $i \in (1,...,k)$,

j – Integration activity, where $j \in (1,...,n)$.

The aspects, that are often highlighted in the literature, were used while constructing the Supply Chain Integration's Degree Measure, emphasizing their key importance. Within the first element the differentiation of integration direction was made, thus it determines whether there is a downward integration with suppliers or an upward integration with customers or integration in both directions. The second aspect analyzed the rang of integration - areas of cooperation. In the next step, the level of integration was analyzed, which can be described as the degree of development of integration activities, respectively in both directions, supplier (ILS) and customers (ILC) within the areas of cooperation defined in

[5] For more details, please see the work of S. Jarzębowski (2013).

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the previous step (the IRS and IRC). The level of integration was measured as the number of activities in the areas and scope of sophistication of integration practices (in the scale of low, medium and high).

4. Conclusions

Within the framework of the paper the theoretical background for efficiency assessment of entire supply chain is analyzed. Based on the presented approaches some implications for modeling of interdependence between the individual stages of food supply chain and for efficiency modeling of entire food supply chain are included in the paper.

As mentioned in the paper, the low growth rate of demand for agri-food products must determine the change of efficiency-based relations treated as a main growth factor in the food sector. Within the framework of the paper Authors indicate that efficiency of enterprise can be increased if there is a strong cooperation within the entire chain. 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.

The Authors believe that by taking into account the interactions occurring between the different stages of the food supply chain and the complex structure of activities within and between companies from the agri-food sector the search for potential improvement of efficiency is not the task not only for single enterprises but also for entire supply chains. Therefore the supply chain must be viewed as one entity and any measurement system should span the entire supply chain. Managers need to see the areas where supply chain performance can be improved, so they can focus their attention, and obtain higher levels of performance. Thus, more research is needed to develop supply chain metrics and to overcome the implementation barriers. There is a need for a collaborative work of managers of entire supply chain on developing aligned metrics for efficiency assessment. The alignment of metrics enables managers to identify and institutionalize the organizational, operational and behavioral changes needed to manage relationship in the supply chain. Aligned metrics can assist in shifting managers' focus to attaining the operational goals of the enterprise-wide supply chain.

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