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Stochastic perspective of industrial distribution network processes

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ABSTRACT

This article investigates contemporary distribution processes in the industrial market. The main trend in distribution during the recent decades manifests itself in a growing number of network-type distribution chains. Based on the evolutionary trends in distribution research, we came up with the idea to investigate distribution networks processes using mathematical tools of probability theory. We consider a distribution network in a stochastic way, where a focal agent optimizes the distribution chain at each decision-making node by switching between possible partners. This allows us to apply time-homogeneous Markov chains theory to explore the partner selection process. We present an approach that allows for the estimating of implicit non-price variables of partner choice in a supply chain. The approach is based on the research context of the transitional Russian economy.

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1. Introduction

The distribution process in industrial markets is seen from a relationship perspective, where the relationship is defined as mutually oriented interaction between two reciprocally committed parties (Håkansson & Snehota, 1995). From our point of view, the network approach is in line with the main trend of recent decades, manifesting itself in a growing number of network-type distribution chains, which are "webs of capabilities embedded in an extended enterprise" (Narus & Anderson, 1996). Firms increasingly depend on the resources controlled by other actors and thereby are "able to combine resources in new ways, gain additional resources, and dispose of superfluous resources." (Wilson & Daniel, 2007). Such distribution practice allows for tailoring to individual end-user requirements (Ford & Gadde, 2008). This paper takes the network paradigm (Achrol, 1997; Ford, 1991) as a main basis of investigation in looking at the development of distribution.

The hypothesis of our research is that the Markov chain approach can be used for business distribution networks analysis. In this paper, the Markov chain model is suggested as a method to examine distributors' behavior in a network. The model makes it possible to take into account the focal network agent (distributor) switching between the company and its competitors. The delivery is optimized by the focal agent at each decision-making node. Therefore, a probabilistic methodology of the network formation process can be used. The Markov chains approach has already been successfully used for modeling, decision making analysis, forecasting, and optimization in different fields such as IT, manufacturing, agriculture, and medicine.

The research questions are stated as follows:

- RQ1: What are the characteristics of the distribution process in the emerging market of Russia?
- RQ2: What are the common features between distribution network activities and probabilistic processes, especially with the Markov chain?
- RQ3: How can Markov chain theory be applied to the business distribution network analysis?

The empirical part of the paper presents an embedded case study, which provides an integrated, detailed examination of an example of a class of phenomena (Yin, 2009). In fact, single-case research often provides better theoretical insights than does multiple-case research (Dayer & Wilkins, 1991). In line with the methodology (Eisenhardt & Graebener, 2007; Flyvbjerg, 2006), the case of the Russian distribution company in the chemical industry is described. With the general aim of investigating the opportunity to apply probabilistic theory to the distribution process, this paper searches for similarities between the distribution chain and Markov chains. The unit of analysis is the channel from producer to distributor, with a range of network relationships. The results are reflected by graphs and descriptions of the channels.

With these aims, the paper is organized around the following topics. Firstly, we give an overview of the literature, history, and ongoing changes in distribution. Secondly, we aim to give brief insight into Markov chain theory and its application to business networks. Thirdly, we focus on the case study and a description of three types of supply chains. Fourthly, we present a stochastic model of distribution

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and explore the process of selecting partners using a time-homogeneous Markov chains approach. Finally, we present suggestions as to how Markov chain theory could be applied to business networks. The first example shows how, using a transaction matrix, we attempt to predict the network composition in *n* steps. Also the concept for an estimation of non-price variables parameters is formulated.

2. Theoretical background

2.1. Concept of distribution and evolutionary trends in research

Over the past two decades, the literature has increasingly moved to consider inter-firm networks as an efficient form of organizing business activities (Rumyantseva & Tretyak, 2003). Business networks can be viewed as inter-firm exchange relationships or as interconnections between autonomous business units, either initiated by the supplier or the buyer, whereby both parties recognize their mutual dependence and interest in each other's resources (Cunningham, 1980). The involved parties are free to enter into, maintain, or dissolve these relationships and networks (Kamp, 2004). The distribution reality becomes network-like as well.

The term 'distribution' appears in business organization theory at the beginning of the 20th century. Samuel Sparling was the pioneer in distribution study. He pointed out three general classes of business activities: extracting, manufacturing and distributive. Furthermore, he separated the two forms of distributive activities into marketing proper and those activities that facilitate exchange. Marketing was referred to as following "the commercial processes which are concerned with the distribution of raw materials of production and finished output of the factory…The function is to give additional value to the commodities through exchange" (Sparling, 1906). A similar view of the role of distribution was expressed by Weld in 1917 (Weld, 1917), who defined marketing as "the services that must be performed in getting commodities from producer to consumer." (Ford & Gadde, 2008) In fact, distribution comprised all commercial and marketing activities. These activities were identified as functions of distribution originally introduced by Shaw (1912).Based on the idea that distribution involves selling (demand creation) as well as buying (assembly of goods), Clark (1923) systematized seven functions of distributors: assembling, storing, bearing risk, financing, rearranging, selling and transportation. The distribution approach dominated marketing thought in the first half of the twentieth century and has been described as the concept that contributed the most to the development of marketing as a science (Hunt & Goolsby, 1988). Later, distribution was separated from marketing.

Alderson was the first person to present a systematic approach to distribution. Alderson made a distinguished contribution to distribution theory, and for his practical work on distribution cost analysis, he was inducted into the Distribution Hall of Fame in 1953. Furthermore, the new frame of reference slowly moved distribution research "to a focus on how the channel captain should behave to secure an efficient distribution of his products."(Gripsrud, Jahre, & Persson, 2006).

In the middle of the 20th century, a number of terms were proposed in identifying the new field of study: Physical Distribution, Business Logistics, Marketing Logistics, Marketing Logistics, Distribution Planning, and Logistical Management (Bartels, 1988). The significance of the subject increased considerably when physical distribution management in manufacturing firms was recognized as a separate organizational function. One of the most popular logistic management concepts today, addressing inter-organizational issues, is supply chain management (SCM). Since its introduction in the early 1980s by Oliver and Webber, SCM was further developed by Harland (1996), Bechtel and Jayaram (1997), Svensson (2002), Heikkilä (2002), Christopher, Payen, and Ballantyne (1991), Handfield and Nichols (1999). Today SCM represents the most current approach to distribution arrangements, which, in trying to "capture" the "whole" supply chain, take the increased complexity of these arrangements into consideration (Table 1).

To enhance our understanding of distribution arrangements, one must realize that there are interdependencies between activities, actors, and the resources that they use. Whereas the marketing channels approach puts greater emphasis on the actors taking part in the distribution arrangements, business logistics focuses on the activities performed regardless of who performs them. SCM may be regarded as an attempt to combine the two approaches. However, the resource dimension has only received attention in relatively recent lines of research in SCM and in industrial networks (Gadde, 2000; Gripsrud, 2004; Håkansson & Waluszewski, 2002; Håkansson & Snehota, 1995; Jahre & Fabbe-Costes, 2005), wherein the firm is seen as "a collection of resources" (Penrose, 1995).

Our research is concentrated on the distribution service provider's activity in business-to-business markets. Contemporary industrial distribution is considered to have undergone a process of significant evolution. The basic function of distribution has been expressed as to "somehow bring together heterogeneous supply on the one hand and heterogeneous demand on the other" (Alderson, 1965). This task is still the same, but technical developments in logistics, manufacturing, and information exchange make new distribution solutions possible.

One of the major modifications in distribution is a shift away from mass-distribution towards individualized solutions for particular customers (Wilson & Daniel, 2007), or a shift from standardisation to customization (Lampel & Mintzberg, 1996). This is primarily an outcome of developments in the resource layer, where the importance of large-scale operations has been reduced. Flexible manufacturing systems have shortened production lead-times in the same way that efficient logistics have improved distribution. Just-in-time delivery is one example of enhanced customization. These arrangements are built on tight synchronization and increased interdependency among activities. Another effect of reduced lead-times and improvements in information exchange is an increased attention to build-to-order production (Gunasekaran & Ngai, 2005). These arrangements also call for extensive coordination of activities because buffers in terms of inventories will be reduced.

Customization calls for a variety of distribution solutions, and for suppliers, the design of 'multi-channels' has become an important strategic issue (Weinberg, Parise, & Guinan, 2007). Actors involved in these arrangements tend to be specialized in various ways in order to play a particular role in bridging the distribution gap. Following the ARA model (activities–resources–actors) there are changes in three network layers: increased customization in the resource level, growth of interdependency in the activity level, and higher specialization in the actor layer.

The process of significant evolution in business-to-business distribution is accepted worldwide, as well as in Russia (Frauendorf, Kaehm, & Kleinaltenkamp, 2007; Gadde, 2000; Gadde & Snehota, 2001; Ghauri & Lorentz, 2010; Tretyak & Sheresheva, 2005). Distribution strategy is now recognized as a key factor in enhancing customer satisfaction, which is crucial for inter-firm network success. The distributor, not long ago considered mainly a passive collector of orders, is now seen as an agent holding the core position in the supply chain. First of all, the distributor selects appropriate network actors to decrease business risk and improve efficiency. Choice of partners is one of the most important managerial decisions in networking (Jadgev & Browne, 1998; Mikhailov, 2002; Tallura & Backer, 1996). The distributor invests effort in integrating manufacturers, suppliers of different services, and customers in the supply network to cope with the issues of optimal quantity, cost, and quality.

A *distribution network* is an entire chain of distribution intermediaries from the supplier to the consumer. The distributor acts as an intermediary in the chain, performing a number of important functions (Webster, 1991) including buying, selling, financing, storage, sorting (breaking bulk), grading (quality assessment),

Table 1
Evolutionary trends on a distribution research.

Time period	Dominant theory	Approach	Focus	Unit of analysis	Major references	Comments
1900–1950	Historical school of economics	Functionalists	Functions and flows	Whole system	Sparling (1906) Shaw (1912) Clark (1923)	▪ Distribution arrangement ▪ Functions
1950–1970	Neoclassical economics	Functionalists/ managerial	Costs	System/company	Alderson (1957) Bucklin (1965, 1966)	▪ Distribution strategies ▪ Postponement-speculation principle ▪ Vertical marketing systems
1970–present	Social psychology and political science	Managerial	Power and conflict	Dyad	Stern (1969) Gaski (1984)	▪ Behavioural ▪ Channel leader
	New institutional theory/ transaction cost economics	Managerial	Transactions	Dyad	Heide (1994) Wathne & Heide (2004) Williamson (1973,1993)	▪ Transaction costs ▪ Governance structure ▪ Satisfaction, fairness, trust
	New institutional theory/ new economy	Managerial	Relationships	Network	Iacobucci & Hopkins (1992) Achrol (1991, 1997) Gadde and Ford (2008) Anderson et al. (1994)	▪ Network environment ▪ Relationships ▪ Interdependences

(Adapted: Ford & Gadde, 2008; Gripsrud, 2004; Wilkinson, 2001).

transportation (logistics), providing market information, and also risk-taking. That is why a distributor is considered to be not only a reseller, but also an actor adding *value for the customer*. A strong and efficient distribution network, which is often headed by focal firm ("chain captain"), helps to reduce costs while providing goods and services to the consumer. Resource sharing in distribution serves as the foundation for building sustainable competitive advantage because of the increase of resources available to the company and the increase in flexibility (Weber, 2001).

The role of a distributor in a supply chain is now considered to be crucial for establishing relations with numerous agents specializing in specific distribution functions: transport companies, finance organizations, custom brokers, etc. The interconnection of firms' activities generates and is increased by interconnected relationships that outline the network approach within the supply chain (Cantu, Montagnini, & Sebastiani, 2009).

A wide range of economic and mathematical methods is used for network organization analysis. Next we will give a scheme of methods, which was composed by Egorova (2006) (Fig. 1).

Thus a distribution network is recognized as a complex system, which requires a special research and management approach. In our research, we assume that probability theory can be fruitfully used for business networks analysis, particularly Markov's chain theory.

Contemporary post-neoclassical science considers reality not just in the form of a self-evolving integrity but also as something unstable, fluctuating, and chaotic. The instability of the world does not mean, however, that it cannot be investigated. Moreover, disequilibrium should not be avoided as something inherently negative or harmful. Imbalance in an organization can act as a condition for stable and dynamic development, when inviable elements are excluding and abolishing. Stability is replaced with instability; the appearance of new forms heralds the destruction of others. Erratic phenomenon cannot be controlled in the same way as social behavior (Prigogine & Nicolis, 1977). Probability, instability, and uncertainty are integral parts of the present-day management science.

2.2. Introduction to Markov's chain theory

The Markov chain was named for Russian Prof. Andrei A. Markov (1856–1922), who first published his results in 1906. His research on Markov chains launched the study of stochastic processes, which have many applications.

Markov chains are used as a tool for network research in almost all fields of modern applied mathematics, so we expect them to be appropriate for the business networks analysis. This section gives a very brief introduction to a discrete-time Markov chain. For more details, one can consult the books by Ross (2000), Haggstrom (2002), Meyn and Tweedie (1993), Puterman (1994), Wai-Ki and Michael (2006).

Research on network formation is generally motivated by the observation that social structure is important in a wide range of interactions. Very popular tools in modeling networks are those of graph theory. A network is considered using either a non-directed or a directed graph; the type of graph is chosen depending on the context.

There are two main types of network formation models. The first type is derived from random graph theory considering an economic or social relationship as a random variable. The other uses game theory tools and examines actors (people, or firms, or other actors involved) as they exercise discretion in forming relationships.

In this paper, we will focus on the random graphs as formal models used for exploration of the network formation: a good example is a pure Bernoulli process of link formation (Erdös & Rényi, 1960). Let us consider a network where the (non-directed) link between any two nodes is formed with some probability p (where $1>p>0$), and this process occurs independently across pairs of nodes. Such a random method of forming links potentially allows the emergence of any network, yet some networks are more likely to emerge than are others. Moreover, as the number of nodes becomes larger, there is much that can be deduced as to what structure the network is likely to take, as a function of p. Such a random graph exhibits a number of 'phase' transitions as the probability of forming links, p, which is varied in relation to the number of nodes, n; that is, resulting networks exhibit different characteristics depending on the relative sizes of p and n.

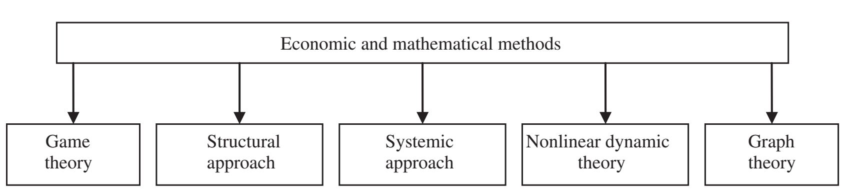

Fig. 1. Economic and mathematical methods used for network analysis.

Advanced random-based models of networks take into consideration the most basic network property, namely, that the presence of links tends to be correlated. On an intuitive level, models of network formation where links are formed independently tend to look too much like 'trees', whereas observed social and economic networks tend to exhibit substantial clustering, with many more cycles than would be generated at random (Watts, 1999, 2001).

Frank and Strauss (1986) identified a class of random graphs that generalize Bernoulli random graphs, referred to as p^* networks or 'Markov graphs.' Their idea was to allow for the chance that the formation of a given link is dependent on whether neighboring links are formed. Specific interdependencies require special structures because, for instance, making one link dependent on a second, and the second on the third, can imply some interdependencies between the first and third. These sorts of dependencies are difficult to analyze in a tractable manner, but nevertheless, some special versions of such models have been useful in statistical estimations of networks (Jackson, 2008).

Formally, a Markov chain is a discrete random process with the Markov property (Markov, 1906; Markov, 1971). A discrete random process means a system that can be in various states and which changes randomly in discrete steps.

The Markov property states that the conditional distribution of X_{n+1} given $(X_0,\ldots, X_n)$ depends only on X_n. In other words, to make the best possible prediction of what happens "tomorrow" (time $n+1$), we only need to consider what happens "today" (time n), as the "past" (times 0, …, $n-1$) gives no additional useful information. This phenomenon is called the memoryless property of a system. Formally,

$$\Pr(X_{n+1} = x|X_1 = x_1, X_2 = x_2 \ldots, X_n = x_n) = \Pr(X_{n+1} = x|X_n = x_n) \tag{1}$$

This property corresponds to the contemporary business situation, when very often the probability of choice only depends on the current state and not on the state of the system at previous steps.

The possible values of $\mathbf{x_i}$ form a countable set S called the state space of the chain.

Another interesting feature of this random process is that the conditional distribution of X_{n+1}, given that $X_n = v2$, for example, is the same for all n. This is because the mechanism that the walker uses to decide where to go next is the same at all times. This property is known as time homogeneity, or simply as homogeneity. Assuming homogeneity is nothing but a tool that helps simplify the analysis (Müller & Köberl, 2010). The elements of the transition matrix P are called transition probabilities.

Let P be a $k\times k$ matrix with elements $\{P_{i,j}: i, j=1, \ldots, k\}$. A random process $(X_0, X_1, \ldots)$ with finite state space $S=\{s_1, \ldots, s_k\}$ is said to be a (homogeneous) Markov chain with transition matrix P, if for all n, all i, $j \ni \{1, \ldots, k\}$ and all $i_0, \ldots, i_{n-1} \ni \{1, \ldots, k\}$ we have

$$P\Big(X_{n+1} = s_j|X_0 = s_{i0}, X1 = s_{i1}, \ldots, X_{n-1} = s_{in-1}, X_n = s_i\Big) = P\Big(X_{n+1} = s_j|Xn = s_i\Big) = P_{i,j}. \tag{2}$$

We next consider another important characteristic (besides the transition matrix) of a Markov chain $(X_0, X_1, \ldots)$, namely the initial distribution, which tells us how the Markov chain starts. The initial distribution is represented as a row vector $\pi^{(0)}$given by

$$\pi^{(0)} = \Big(\pi_1^{(0)}, \pi_2^{(0)} \ldots \pi_k^{(0)}\Big) = (P(x_0 = s_1), P(x_0 = s_2) \ldots P(x_0 = s_k)) \tag{3}$$

Theorem. For a Markov chain $(X_0, X_1, \ldots)$ with state space $\{s_1, \ldots, s_k\}$, initial distribution $\pi^{(0)}$ and transition matrix P, we have for any n that the distribution $\pi^{(n)}$ at time n satisfies

$$\pi^{(n)*} = \Big(P_{ij}\Big)^n \times \pi^{(0)} \tag{4}$$

A useful way to picture a Markov chain is its so-called transition graph. The transition graph consists of nodes representing the states of the Markov chain and arrows between the nodes, representing transition probabilities (Haggstrom, 2002; Sokolov & Chistykova, 2005).

3. Distribution networks in Russia

3.1. History overview

Russia, as an economy in transition, provides a unique opportunity to investigate changing and adapting network structures, stakeholder interactions, and relationship constellations. The nature of relationships in Russia was analyzed recently in a few papers (e.g. Davis, Patterson, & Grazin, 1996; Kolesnik, 2010; Smirnova & Kouchtch, 2007; Sheresheva, 2006; Tretyak & Sheresheva, 2005; Tretyak & Popov, 2009). The emerging Russian economy has some specific factors, including the instability of the market, a lack of information on potential partners, and a higher propensity for opportunistic behavior (Halinen & Salmi, 2001; Johanson, 2007; Smirnova, Podmetina, Vaatanen, S., & Kouchtch, 2009). Distribution in Russia is characterized by some trends, including a shift in distribution channels' structure, thereby cutting the number of distributors in many industries, an internalization of distribution networks, and the growing role of information infrastructure (Butler & Purchase, 2008; Ghauri & Lorentz, 2010; Hanf, Pall, & Sheresheva, 2010; Sheresheva, 2005, 2010). Still, there is a need for more research because the empirical data are scarce, especially on networking in particular branches of the Russian economy.

Over the last decade, the basic economic infrastructure formed, followed by the emergence of distribution networks. Due to the intensive spread of Information and Communication Technologies, building of inter-firm networks became less costly, and a number of sustainable distribution networks started to grow (Kolesnik, 2011). It is precisely this last decade's developments that will be the main focus of our research based on the data on chemical distribution channels of the western part of the Russian Federation.

A stochastic approach is based on the business context of the distribution company case study. We have constructed a visual graph of the distribution network. The unit of analysis is a channel from producer to distributor, with a range of network relationships. The embedded case study lasted more than a year, with the aim of understanding the nature of distribution and the challenges of working. With the general aim of investigating the opportunity to apply probabilistic theory to distribution process, this paper seeks similarities between the distribution chain and Markov chains.

3.2. Case company overview

This section provides the background of the focal company. The case company is the distributor of a wide range of chemicals for production (such as polymers, rubber, paints, and inorganic components). The Joint Stock Company started its operations in 2000. Over 10 years, the distribution network of the company has been expanded to 10 divisions: Moscow, Saint-Petersburg, Tambov, Volgograd, Kazan, Yekaterinburg, Yaroslavl, Ivanovo, Rostov-on-Don, Perm, and Minsk (Belarus).The wholesaler has an annual turnover of approximately 50 million USD and more than 100 employees.

The company puts strategic emphasis on the provision of a wide range of chemicals for small and medium producers, which are the target market.

The company has established relationships with suppliers from all over the world. The middleman coordinates three chain types:

1) Russian – purchasing of goods from domestic producers.
2) European – purchasing of goods from the European suppliers: Belgium, Germany, Italy, Switzerland.

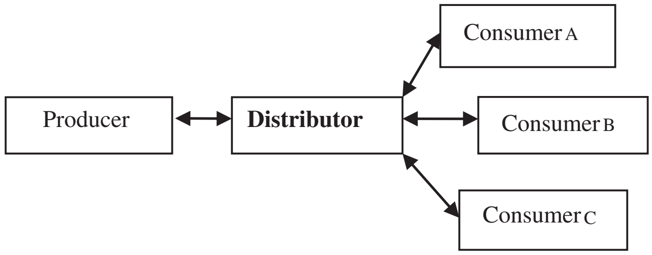

Fig. 2. Graph of domestic distribution network.

3) Asian – purchasing of goods of Asian origin: China, Taiwan, South Korea, India.

The following sections proceed to address three specific types of channels with special emphasis on the actors and the relations among them.

3.3. Domestic distribution network profile

The majority of domestic suppliers have common characteristics. Most of them were founded in the USRR, and their production quality is rather poor due to low tech and outdated equipment. The government protects local producers by means of import duties regulation. On the one hand, such measures help companies to survive; on the other hand, its gives no stimulus for the development of skills and innovations. Marketing activities and services of such domestic suppliers are rather poor. Products are sold on the Ex Works terms.

Social contacts build the main components of the "entirely domestic" chains. Personal relationships are the main basis of business, so such a network is close to the type described by Granovetter (1983). Therefore, major issues could be resolved in private discussion by telephone.

The producer is interested in more "transactional" than "relational" ties. They are seeking a middleman who is able to purchase in bulk and to guarantee payment in time. The distributor organizes transportation using its own transport facilities or carrier service for the delivery of goods to the warehouse in the Moscow region.

The graph of domestic distribution channel is as follows (Fig. 2):

The chain may be even shorter if the factory ships the goods directly to the final consumer.

It is an example of a producer-powered network. The relationships between partners recently faced serious challenges due to socio-economic reasons, so it is important to diversify suppliers, and the additional supply from European companies was considered the best decision.

3.4. Profile of distribution network from a European supplier

Cooperation with foreign suppliers is a good opportunity to extend a product line and thus to attract more consumers. It is important to mention that international relations have a positive impact on the image of the company.

The distribution channel is rather complex, as shown by the graph below; products going through the chain are usually unique, branded, and of high quality, and are thus expensive (Fig. 3).

Large European chemical producers provide financial support, e.g., the postponement of payment, to reliable partners, but it takes a certain amount of time and effort to prove reliability.

European suppliers consider the BRIC markets to be very good prospects and thus intend to expand, looking for further projects. As a result, transactions tend to increase constantly, being quite regular and stable. The well-known European companies are open to the cooperation, and most of them have representative offices in Moscow, which are good to help facilitate the development of relationships.

Communications in this chain are, to a certain extent, formalized and poorly developed. On the one hand, formalizing communications seems quite sound in terms of some business processes, such as the placement of orders, the arrangement of the receipt of shipping documents, payment, etc. On the other hand, underdeveloped communications prevent taking into account the special demands and requests of the consumer. Exchange of information occurs mainly between representatives working in the Russian office and customer care managers in the point of shipment in Europe. Therefore, the distribution efficiency strongly depends on personal relationships and the individual qualities of certain persons. As to strategic issues of business relationships, they are usually defined on the CEO level.

European products are well known to Russian companies, but overall demand for these products is quite modest due to the high price. For this reason, European suppliers compete with numerous Asian producers.

3.5. Profile of distribution network from Asian supplier

Asian suppliers from China, Korea, and India often offer a lower price than their European counterparts. Price–quality ratio for products from Asia is quite acceptable. Supply companies intensively participate in industrial exhibitions, which become the main source for partnering. The interaction process between Russian and Asian firms is hindered by language and culture differences.

The main obstacle for the development of effective relationships is the long lead-time of 45 to 60 days. Risks increase considerably due to the constant resource's price dynamic. The price of the offer depends on the stock exchange price and the demand on the local market. The final consumer price varies greatly, correlating with the fluctuations of the ruble to dollar exchange rate. Due to the reasons mentioned, transactions with Asian producers are quite risky. Nevertheless Asian goods account for a considerable share of trade flow. The supply chain graph looks as follows (Fig. 4):

The common feature of all chain types is the constant partner dynamic. These observations have given us the idea that distribution network could be described in terms of probability theory, mainly because the structure of any chains is not determinative and because the configuration of participants is changing.

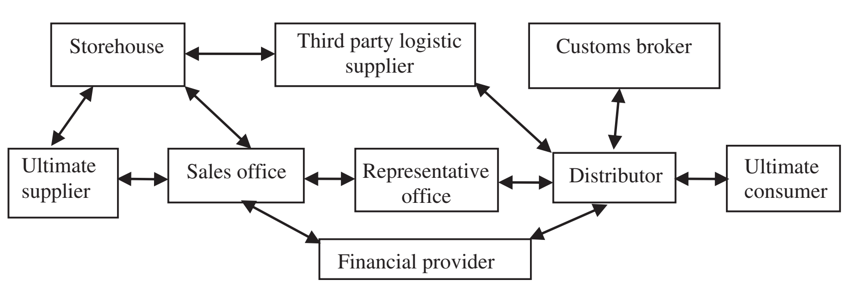

Fig. 3. Graph of distribution network from European supplier.

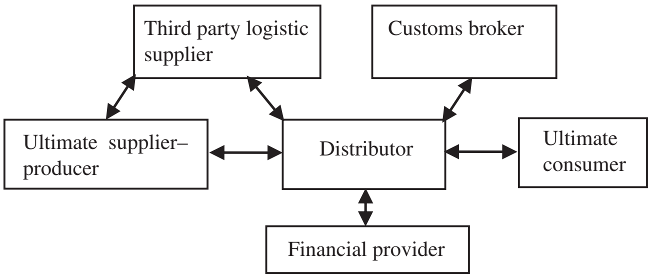

Fig. 4. Graph of distribution network from Asian supplier.

4. Markov chain theory applications to the business distribution networks

4.1. Network formation process and Markov chain theory

In this section, a trial attempt to apply Markov's chain theory to the distribution network analysis was undertaken. We built up the research presuming that a time-homogeneous Markov chain has numerous similarities with a business distribution chain on the emerging market:

1) The probabilities of future states of the process depend only on the present state, and not on the state of the system at previous steps. Indeed when the focal agent makes a choice of partner from the pull of suppliers, it takes into consideration the ongoing situation. For example if $\boldsymbol{i_1}$ partner was chosen more frequently than others, this fact would not have a large impact on the current choice results.
2) The distribution process is the consequence of steps, where each choice is the state of a system. Markov theory is applicable in describing such a process in discrete time. Howard provides us with a picturesque description of a Markov chain as a frog jumping on a set of lily pads (Howard, 1971). The frog starts on one of the pads and then jumps from lily pad to lily pad with the appropriate transition probabilities. In a business case it can be represented by sequence of transactions between network agents.

We aim to describe the process of choosing a partner from the pull or set of homogenous network agents providing similar goods or services (e.g., product, credit, transport, and storehouse) for a distributor.

Let the set of system's statuses (i_1, i_2,…, i_N) be the set of homogenous agents. Each step is one transaction with one of the agents. At each decision-making node the distributor selects the "best" partner aiming to optimize the delivery. He chooses among partners in the network, but not from all existing participants in the market. So we know the number of possible chain states. In the network there may be several suppliers of one product, several carriers, etc. The distributor can link with any partner from the network with some probability (Fig. 5).

The distributor makes a choice based on different parameters or factors. For example, probabilities of distributors' behavior can be assigned according to prices. In that case actors $i_1, i_2,\ldots, i_N$ offer prices $a_1, a_2,\ldots, a_N$ and ξ is random variables that adopts the values$i_1, i_2,\ldots, i_N$. Probability of the choice of actor i_k(distribution of ξ) can be then set as

$$P(\xi = i_k) = \frac{(a_k)^{-1}}{\sum_{j=1}^{N} \left(a_j\right)^{-1}} \tag{5}$$

In terms of Markov chain theory, we have a vector of the starting distribution of probabilities $\pi^{(0)} = (p(\xi = i_1),\ldots, p(\xi = i_N))$.

The probabilities of transition are, for example,

$$\Pr\left(\xi_{n+1} = j \,/\, \xi_n = i\right) = p_{ij} = I\left(a_j \le a_i\right) \times \left(\frac{\left(a_j\right)^{-1}}{\sum_{(k:a_k \le a_i)} (a_k)^{-1}}\right) \tag{6}$$

where $I(a_j \le a_i)$ is an indicator function.

Then the one-step transition matrix is given by

$$P_{ij} = \begin{pmatrix} P_{11} & P_{12} & P_{1m} \\ P_{21} & P_{22} & P_{2m} \\ \ldots & \ldots & \ldots \\ P_{m1} & P_{m2} & P_{mm} \end{pmatrix} \tag{7}$$

For better understanding of the issue, allow us to give an example of transition probability matrix for supply chain with a rigid structure. For hierarchically organized chains, there is no option for partner choice. So the transition probability matrix will have the following meanings: $p_{ik} = 1$; $p_{ij} = 0, j \ne k$, if i_k is our fixed partner.

The matrix of transition probabilities would be the following:

$$P_{(ij)} = \begin{pmatrix} 0 & 1 & 0 \\ 0 & 1 & 0 \\ 0 & 1 & 0 \end{pmatrix}$$

In that case, we can easily predict the probability of a distributor's choice on each step n, because it is determined. This matrix shows that the probability of choosing our permanent partner (i_2) equals 100%. Choice is independent from terms and conditions offered by the agents.

The purpose of our research is to explore distributors' behavior in flexible or network-like structured supply chains. To apply a Markov chain model, we have to estimate transition probabilities based on the practical data. For example, there are three transport companies (i_1,i_2,i_3) who provide logistic services. In business, the choice of a carrier depends

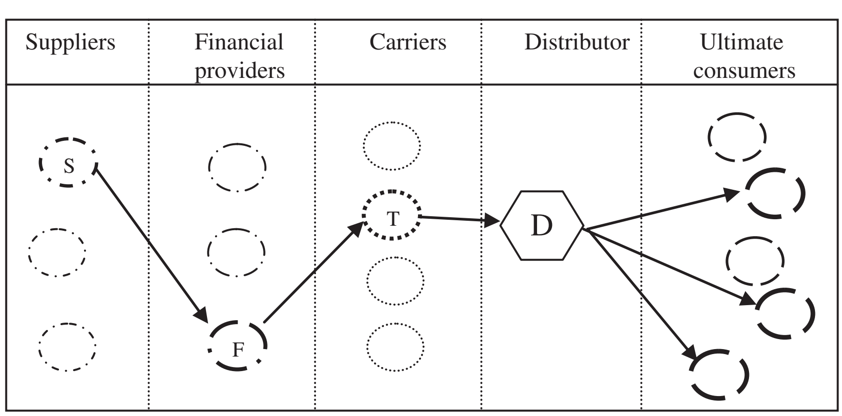

Fig. 5. Distributor chooses partners for the supply chain from the pull of actors.

on a variety of factors which may differ from shipment to shipment. In that case, we assume that choice is only driven by price. In order to eliminate these factors, we have made a request for delivery of the same shipment.

We considered the transport rates for delivery of 20 tons of the product from the storehouse of supplier (A) to the storehouse of distributor (B) from three carriers ($m=3$) given by {3500, 3650, 3700}euro.

According to the formula (3), the initial distribution will be as follows

$$\pi^{(0)} = (0.323 \quad 0.335 \quad 0.341)$$

To be clearer, allow us to give an example of the calculation:

$$\pi_1^{(0)} = \frac{3500}{(3500+3650+3700)} = 0.323$$

A one-step matrix of transition probabilities (P_{ij}) according to the formula (6) will be the following

$$P_{11} = I\left(a_j \le a_i\right) \times \left(\frac{\left(a_j\right)^{-1}}{\sum\limits_{(k:a_k \le a_i)} (a_k)^{-1}}\right) = \left(\frac{\frac{1}{3500}}{\sum\limits_{a_{k\le 3500}} \frac{1}{3500}}\right) = 1$$

For P_{12} and P_{13} would be equal to 0 because there are no rates (a_k) less than 3500 (a_i).

$$P_{21} = I\left(a_j \le a_i\right) \times \left(\frac{\left(a_j\right)^{-1}}{\sum\limits_{(k:a_k \le a_i)} (a_k)^{-1}}\right) = \left(\frac{\frac{1}{3500}}{\sum\limits_{a_{k\le 3650}} (a_k)^{-1}}\right)$$

$$= \left(\frac{\frac{1}{3500}}{\frac{1}{3500}+\frac{1}{3650}}\right) \approx 0.511$$

$$P_{22} = I\left(a_j \le a_i\right) \times \left(\frac{\left(a_j\right)^{-1}}{\sum\limits_{(k:a_k \le a_i)} (a_k)^{-1}}\right) = \left(\frac{\frac{1}{3650}}{\sum\limits_{a_{k\le 3650}} \frac{1}{3500}+\frac{1}{3650}}\right)$$

$$= 0.489$$

Finally we get the following matrix of transition probabilities:

$$\left(P_{ij}\right) \; P_{ij} = \begin{pmatrix} 1 & 0 & 0 \\ 0.511 & 0.489 & 0 \\ 0.351 & 0.327 & 0.322 \end{pmatrix}$$

The matrix shows the probability of moving from one partner to another. We see that probability is higher for the transport company with the lower price. However, there is always some probability that we will not choose an agent with the best price offer.

The lower row of the matrix shows that all companies may have equal chances. This situation is possibly due to several reasons. First, in our case, the price difference is insignificant. Second, price may not play the key role in decision-making process.

We can try to predict our partner in the future. For example, who will be our partner in five steps? It is important to mention a limitation of research: carriers will not change their prices within the reviewed period of time. So we raise our matrix of transition probabilities to the power of 5.

$$P_{ij}^{(5)} = \begin{pmatrix} 1 & 0 & 0 \\ 0.518 & 0.482 & 0 \\ 0.351 & 0.327 & 0.322 \end{pmatrix}^5 = \begin{pmatrix} 1 & 0 & 0 \\ 0.97 & 0.03 & 0 \\ 0.95 & 0.05 & 0 \end{pmatrix}$$

Then the distribution according to the formula (4) would be following:

$$\pi^{(5)} = \pi^{(0)} \times \left(P_{ij}\right)^5 = (0.323 \quad 0.335 \quad 0.341) \times \begin{pmatrix} 1 & 0 & 0 \\ 0.97 & 0.03 & 0 \\ 0.95 & 0.05 & 0 \end{pmatrix}$$
$$\approx (1 \quad 0 \quad 0)$$

The above example shows that the focal agent rapidly tends to choose the cheapest partner even in a few steps. This is just one example of a possible application of Markov theory to the business field.

4.2. Estimation of trust via Markov chain theory approach

Let us look at another way of applying probability theory to business.

Behavior of a distributor in a network is not solely price driven. In business, implicit parameters, such as trust and commitment, play an important role. So the ultimate decision in a distribution network chain is based on implicit and explicit benefits.

Implicit parameters are very difficult to measure because it is hard to estimate them directly. Usually an interview is used to estimate hidden benefits, as managers evaluate it intuitively. Furthermore, we propose an idea of how to estimate non-price variables based on theoretical and empirical probabilities.

Further development of the research would be to find a solution in computing a matrix of transition probabilities based not only on the information about rates, but also taking into consideration trust to the partner. In this regard, the special issue is the evaluation and formalization of trust.

Let us introduce parameter "T", which will be used for the designation of non-price variables or implicit costs. We assume that the greater the value of T, the more trust between the partners.

The steps are as follows:

1. Introduce parameter C, which shows the relation between price and trust or explicit and implicit parameters.

$$C_i = \frac{T_i}{a_i} \tag{8}$$

2. Calculate an empirical transition probabilities matrix ($\pi_{empir.}$) for state n, based on practical data of a distribution company.
3. Find out initial probability distribution (π^0) based on an interview of the managerial stuff of a company.
4. Calculate theoretical transition probabilities P_{ij}.
5. We propose the following formula for calculation of transition probabilities $P_{(ij)}$,

$$P_{ij} = \frac{NP_j - P_i + 1}{2N - NP_i},$$

which corresponds to the following demands:

$$1)\sum_{j=1}^{N} Pij = 1$$

$$2)\sum_{j=1}^{N} Pij \ge 0$$

$$3)\mathrm{P_{ij}} \le 1 \; for \; \forall i,j$$

6. Using the properties of time-homogeneous Markov chains, we can find the distribution of probabilities at n step according to the formula (3):

$$\pi^{(n)*} = \left(P_{ij}\right)^n \times \pi^{(0)},$$

where $\pi^{(n)^*}$, $\pi^{(0)}$ – are known, and for $(P_{ij})^n$ meaning a parameter is known, and T we aim to find. If the equation has a solution, we can then try to find value of trust in the distributors decisions.

Thus, we have proposed a step-by-step approach for the estimation of implicit factors' share in the decision-making process based on Markov chain theory. Additional research will explore the idea further and will attempt to find the solution to the *T* parameter.

5. Conclusions, limitations, and future work

This paper presents research on the conjunction of business distribution and Markov chains. By coincidence, both subjects were adduced in the same year, 1906, one in the book by Markov and the other in the book by Sparling.

The evolution of the distribution process is presented in this paper. Present-day distribution is characterized by a network-like structure. The contemporary distribution chain is no longer hierarchically structured. It has to be as flexible as possible to adapt quickly to the dynamic business environment and must also be sustainable. Therefore, a distribution network consists of actors who are independent through management and property. The basis of their cooperation is a reciprocal use of each other's resources. The focal agent of the network coordinates the activities of the actors. One of the main tasks of the "chain captain" is to form the chain and to choose appropriate partners for each delivery. Every time the chain captain makes a choice of partners from the pull of actors, he takes into consideration the current situation and tries to optimize the chain. Such behavior makes the process similar to the Markov chain. This view allows us to apply time-homogeneous the Markov chains' approach to explore the partner selection process.

In our research, we have made an attempt to apply the mathematic tools of probability theory. This paper presents two ideas about how the Markov chain approach could be used for business networks.

The most interesting result of this paper is the concept of estimation of non-price variables, parameters based on theoretical and empirical probabilities. Further empirical research should be conducted to check and improve the model. Although even the existing algorithms of Markov chains are quite complex, further results from research could be rather fruitful.

The approach, of course, has limitations, as with any mathematical model. One of the main disadvantages is the impossibility of taking into consideration numerous environmental facts. For example, we have mentioned that the domestic supply chain is strongly influenced by interpersonal relations. Therefore, it seems that the Markov chain approach would be inappropriate for the analysis of such a chain. However, the model would be more appropriate for the exploration of distribution chains from Asia, where personal relations are weak.

Formalization of the distribution process is valuable in terms of science and management. Once we have elaborated an appropriate mathematical model, we would be able to use the incredible possibilities of modern computing machines. Nevertheless, there are some limitations for the use of them in business because mathematical models can hardly reflect a real distribution network. Additionally, results of this paper can be seen by managers as a piece of the puzzle for the complex view of a distribution process.

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