Evolutionary model of Schumpeterian competition on a multi-level network market

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Abstract
In the paper the attention is focused on a problem of analysis of network markets with several market segments where each segment can be interpreted as a different technological standard. To describe dynamics of such markets a computer simulation model is employed. The role of product innovations is explored. The authors analyse such phenomena as possibility of inefficient standards vitality, significant distinction between inter- and intra-segment competition and key force of innovations perpetually shaping the situation on a network market. The model showed patterns that corresponded to some stylized facts witnessed in the telecommunication industry. These regularities were empirically proved for the Russian market for cellular telecommunications.

Keywords: Network externalities and standards; Network competition, Diffusion of innovations; Schumpeterian competition; Telecommunications industry.

JEL classification: L22, L96, B52

12.04.2007

Introduction

Last decades development and globalization of the whole world economy has been caused by innovations in communication technologies. New technologies bring changes in economy and in our lifestyle. So there is no surprise in the growing interest to the telecommunication industry. Analysis and forecast of its development is becoming more and more important today.

Standard economic methods usually give inappropriate tools of analysis of telecommunication markets. Market for telecommunications differs a lot from the ordinary markets that are subject of research of the classical microeconomic theory. Markets for telecommunication services are technology-dependant network markets with a rather complicated structure. It is common when one service is supplied on different technological platforms (for example one can make telephone call through fixed or cellular network or even through Internet) or new technology can be used for different services (triple-play services). Network externalities, which are essential to a telecommunication market, lead to market failures, which include market breakdown due to start-up and problems, as well as inability of industries to switch to a superior standard because of lock-up effects. Market for telecommunications definitely needs more research because many of its features still remain unexplored nowadays. In particular, this applies to empirical research, since measurement of network effects and compatibility in real markets is still a largely uncovered issue.

The objective of our paper is to develop a model, which captures main features of market competition with product innovations on a network market with several market segments where each segment can be interpreted as a different technological standard. As an example, we refer to Russian cellular market, where we investigate inter- and intra-segment competition and a role of product innovations perpetually shaping the situation on a network market.

To build a model we use an evolutionary approach and agent-based computer modelling tools. Nowadays most of research in telecommunications is done within a neoclassical paradigm, where network effects are viewed solely as externalities. The problem is that traditional economic theory learned to deal with negative externalities, but cannot solve equations with positive feedback loops. In neoclassical models of network markets rationality of agents is expanded by gift of perfect foresight and fulfilled expectations. Without this property neoclassical models can hardly be solved. The main problem is not that this supposition seems unrealistic. What is even more important is that in these models a market might fail to appear. If everybody expects that no one would subscribe, then nobody will actually subscribe and it will be an equilibrium situation. We can hardly imagine this situation nowadays.

We argue that the presence of positive network externalities and positive and significant critical mass, which are the key elements of any network market, have significant impact on the analysis of network industries. Therefore, conduct and structure of a network market, as well as performance of agents on such markets, may be significantly different in two models built in different paradigms. Inability to capture the core of network markets in neoclassical models and lack of proper analysis tools make it impossible to build adequate models in neoclassical tradition. This adds up to the choice of an evolutionary approach, where there is both methodological ground and variety of analysis instruments to view market for telecommunications in a proper light without omitting key features seriously influencing behaviour on this market.

Evolutionary models are capable of dealing with variety of preferences, income levels and other characteristics of heterogeneous agents, which play the crucial role in evolutionary models. In such models we simply do not need such strong assumptions like rationality and fulfilment of expectations, which are at least unrealistic. Variety is the key reason for appearance and growth of a network market. This property of evolutionary models makes them applicable in analysis of real network markets. Another issue is calibration of a model to fit real data. One cannot calibrate fulfilled expectations and check if rationality is achieved on different market levels, but she can calibrate income distribution, size of social networks and even distribution of preferences.

There is a vast strand of literature on economics of network markets, where a significant share of papers is devoted to the analysis of a telecommunication industry. The best-studied aspect arises in the adoption of decisions by consumers–a consumer who uses the network goods benefits other consumers (Rohlfs 1974, Economides 1996, Shy 2001, Glazer et al. 2005). The externality is most influencing when a critical mass is needed to sustain the market, which means that a positive incentive for market expansion on all levels is present on some early stage of market evolution. A number of Nash equilibria could arise in such settings, among which there is a problematic equilibrium mentioned before under which network market does not appear and no one wants to buy the good.

Methodology of modelling presented in this paper is based on evolutionary approach. We used basic ideas of Nelson-Winter models (Nelson and Winter 1982) and methodology of "history-friendly" modelling (Malerba et al 2001). Other recent ideas of models built within an evolutionary paradigm have also had serious impact on the model presented in this paper (Winter 1987, Winter, Kaniovski and Dosi 1999, Saviotti and Pyka 2005). We measured variety in technologies and telecommunication services to make the model more realistic. We followed the trail P.-P. Saviotti (Saviotti et al. 2004) blazed and used a measure of variety, based on Weitzman's maximum likelihood procedure, based on the distance between products, which is indicating the degree of differentiation of a product population.

The discussion continues in a following way. We first turn to exploring history of a cellular telecommunication market in Russia, where we aim at deriving some stylised fact of this industry. We then turn to building a framework of an evolutionary model of such market, which we refer to as a multilevel network market to emphasise the importance of network characteristics and existence of a complicated structure on such a market. After establishing the modelling framework we present the calibration procedure of main elements of model entities to show that empirical regularities may and will arise in the calibrated model, as it is a simplified version of a real market. In the end we turn to conclusions, which claim results that have been achieved, and describe their degree of relatedness to other relevant papers.

Stylised facts about history of cellular telecoms market in Russia

Here we describe some stylised facts about development of cellular telecommunications industry in Russia. These are hypothesizes about which are to be explained in our model. One can notice that the same facts could be viewed on different network markets with multi-level structure. We are sure that the model can be applied in the general case. So these are the facts to be explained.

Firstly, number of subscribers for inefficient standards is rather robust even after introduction and diffusion of new technologies. First cellular networks based on analog technology standards NMT 450 and AMPS were introduced in Russia in 1992. The analog service reached the size of around 200 thousand subscribers at the time the second-generation service was introduced in 1995. An interesting fact is that even after second generation services were introduced, analog networks were still expanding for four years. And then, after dominance of GSM technology established, number of subscribers for analog cellular networks stabilised. And even now some first-generation are functioning. This could be explained by sufficiently large switching costs or costumers' preferences, which make people choose cheaper phone calls and neglect new services introduced on second and third-generation networks.

Secondly, more intensive competition is between companies within one market segment. And this competition is a key force that directs the development of a network market. Russia is a unique country where American and European standards compete directly. In early nineties AMPS and NMT-450 competed, later there was a battle between Digital AMPS and GSM standards, now CDMA-2000 is developing and companies are going to introduce UMTS services. And the history proves that the more firms operate within one standard the better is their performance.

Thirdly, on the emerging and developing market concentration index is typically higher than on a developed and stable market. One may claim that development of a market always passes several stages: emergence, rapid growth and stabilization. According to this classification, market concentration peaks during the second phase.

Eventually, 2.5G and 3G standards (CDMA-2000 and EV-DO) in Russia are gaining popularity very slowly. And they do not tend to change GSM standard. The same problems arise in Europe with UMTS standard. Do new technologies have potential to become leading ones or the humanity is going to stop this race of standards and these new technologies will find their unpretentious niches? In the next chapter a model is presented, which is aimed at explaining these regularities and answer these questions.

An evolutionary model of competition on a multisegment network market

This chapter presents a model of competition on a market segment, which consists of several segments. Special feature of this model is that network market is viewed, as opposed to a common treatment, as a multisegment entity. Competition between companies of a given market segment is not the only factor which whips up innovative activity and desire to excel by rival companies but there also strong spillover effects between market segments take place and firms have to trace activities on adjacent market segments in order to retain leading position on a whole market for complementary network products. Active competition drives companies to permanent search for superior technologies and market products that best fits customers' preferences.

In this light the model becomes applicable to assess and gauge effects on the real markets because most important markets today may be characterised by saying 'network market' where firms and consumers enjoy network effects be they strong or not. Simple investigation tells us that virtually all of them have several separated individual sub-market niches which we call 'market segments' in this paper. Importance of such a model is backed up by these facts.

For instance, market for telecommunications is definitely a network market and telephony is a network service, which defines its special features. Consumers' value of a subscription for a new service on this market is most likely to depend on its spread among subscribers.

As it is known from classical papers (Economides 1996, Shy 2001) network market is a market, which has the following properties distinguishing it from a market in a classical definition:

- Complementarity, compatibility and standards;
- Consumption externalities;
- Switching costs and lock-in;
- Significant economies of scale in production.

To explain phenomena arising on such markets and to investigate patterns that we witness on real markets today a model of network market competition is employed. This model is built in the spirit of so-called evolutionary models that have proven to be extremely useful in analysis of innovation diffusion processes. The abovementioned properties of a network market make it very hard or even impossible to investigate model built within a classical approach therefore adding up a lot to the choice of an evolutionary paradigm.

Assumptions of the model follow below.

Assumptions of the model

Market (environment) is composed of *K* segments indexed by *i*, where within each segment (technological standard) there are M_i companies labelled by *j*. Every company provides for network services within a particular standard *i*. Every service is characterized by its *S*-dimensional quality schedule labelled by *s* and is incompatible with services offered by rival companies within a particular standard and between companies of competing standards. Demand side consists of *N* consumers indexed by *k*. Detailed description of system agents follows below.

Model is implemented in discrete time *t=1, ..., T*. The state of the model is formed by market position of all of its components: segments, companies and consumers. Transition from one time period to another is made according to the timing of events in the model, which is presented after the description of the agents.

Segments

Segment is a passive entity in a model, as is the whole network market. The distinguishing feature of a segment is a 'technological ceiling' or an upper bound of a vector of product characteristics that firms may never overcome in their search activity. A network product with characteristics $S_i = \{s_1,...,s_S\}$ on a segment i hence always satisfies $s_i^l \le \overline{s_i^l} \forall l = \overline{1,S}$, where $\overline{S_i} = \{\overline{s_1},...,\overline{s_S}\}$ is the boundary.

Companies

The state of each company at time step t can be characterized by an array of variables and parameters set by a company. In this model this state is $\left(q_j, p_j, \{\theta_J\}_{S=1}^3, D_j\right)$, where q_j is the network size, p_j is the price set by this company, $\{\theta_J\}_{S=1}^3$ is a qualitative characteristic of a service and D_j is the accumulated company debt/profit.

Companies behave according to a number of routines, or rules of behaviour. Main routines of a company are the following:

— Production rule;

— Price-setting rule;

— Search rule;

— Investment rule.

These routines prescribe behaviour to companies in a following way.

Production rule

The cost function all firms face is $c = c(q)$ and is dependent upon the network size. As it is evidenced in a real market for telecommunication systems providing for mobile phone services this function is characterized by increasing returns to scale or simply by $c'(q) < 0$.

If a company wants to implement a new innovation enhancing qualitative features of a service it also has to incur some additional costs associated with application of an innovation to production lines of a company. In this light total cost function company has to face at time step t is $C_t = q_t \cdot c(q_t) + C_{0t} \cdot \lambda_t$, where $\lambda_t = 1$ in case innovation is accepted and applied and $\lambda_t = 0$ otherwise.

Price-setting rule

Price for a new service is set regarding "cost plus profit" rule. Companies can adjust their prices every time step. All of the companies follow the same learning mechanism. If firms see decrease in their market share they choose to decrease their price for some small amount ε (in per cent). In case a firm's position is becoming more solid it decides to increases its price for $\varepsilon/2$. If the situation is stable for a company it doesn't change its routines according to the principle of satisficing behaviour.

This rule is the simplest rule of adaptation to changing environment.

Search rule

Firms in the model are permanently trying to search for new services. The search is costly and firms have to sacrifice part of their profits, α, for these reasons. The more firms spend the higher is the probability that they achieve positive results of their search. Function $\varphi(\alpha)$ defines a probability of a favourable outcome for a company. Outcome is referred to as favourable if the expected quality level of a company's service achieved through innovation exceeds current average quality of its service. This function satisfies the following conditions: (1) $\varphi(0)=0$ or 'you should play the game'; (2) $0<\varphi(\alpha)<1$ or 'if you play you may win'; (3) $\varphi'(\alpha)>0$ or 'the more you invest the higher is the probability of a successful outcome'.

Result of a search procedure is a point in an S-dimensional space of product quality. As far as quality within a particular market segment has some natural upper boundary because provision for services is always based on some technology which can not be advanced infinitely (otherwise we say that a new technological standard or market segment is born) search result must satisfy condition stating that the found product lies within technological boundary, or $s_i^l \le \overline{s_i^l} \forall l=\overline{1,S}$.

Investment rule

Decision to apply a particular innovation is costly for a company and that is a reason why companies have investment rules. Investment rule tells a company which projects are lucrative (in the sense that expected net profit is positive) and which ones are not.

Innovation is adopted in case expected profits from higher demand for the network product net of expenses associated with search and implementation of an innovation are positive. To finance a project firms may use loans with a fixed interest rate r. In this respect firms must incur interest payments and the basic debt and in case they wish to invest further they increase their debt. This process yields the following debt accumulation equation:

$D_t = D_{t-1}(1+r)+In_t-\pi_t$, where

D_t - debt at time t;

In_t - new debt to finance innovations;

π_t - payments made at time t.

Entry and exit

Firms that have been experiencing financial difficulties during $\overline{T}$ time periods, which resulted in positive accumulating debt during these times, shrink because they are inefficient with respect to their investment policies and have to leave the market and give way to firms with superior routines. Newcomers start up randomly at any time period and their characteristics are picked from a sample with a mean of average characteristics within a given market segment.

Following these routines firms set prices for their services, advance qualitative characteristics of their goods and create basis for their future development. But the final quantitative results of firms' behaviour are formed only after an interaction with the demand part of the market system.

Consumers

Demand is formed by *k=1, ..., N* potential consumers – subscribers for network services. Consumers are assumed to be heterogeneous in their estimation of network services, income and alternative utility level. Every consumer has his own relative preference of qualitative characteristics, $\{\vartheta_k\}_{s=1}^{S}$, and utility from subscription to a given network depends on these preferences. Income I_k of a consumer defines a set of available market products; alternative utility cuts off companies that provide for low-quality services which give consumers utility lower than some minimal threshold level $\bar{u}_k$. In the model consumers are described by $\left(choice_k^t, I_k, \{\vartheta_k\}_{s=a}^{S}, \bar{u}_k\right)$, where choice is defined by a set of routines that govern consumers' behaviour.

In order to gain access to the market segments consumers have to incur special costs. Consumers must pay first type of costs, τ, to enter any of the market segments. These costs should be interpreted as costs of buying an adapter, which enables access to a market product. Though, there is another type of costs, η, which is levied on consumers to gain access to a particular product of a given company on any of the market segments. Similarly, these costs reflect the fact that adapter alone is not enough to use market services or goods, because consumers must buy license enabling them to use particular product on the market[1].

Main routines of a consumer are the following:

- Participation rule;
- Choice rule.

These routines prescribe behaviour to consumers in a following way.

Participation rule

Every agent has some initial wealth level I_k. Consumers are ready to spend some part of their income, μ, on purchase of network services. Agent is assumed to be 'active' if he can afford at least one network service in the whole market, in other words if there is a company j such that $P_j \le \mu \cdot I$ for this customer.

Price due to be paid by a given consumer is set in a following manner: $P_j = p_j + \eta * \lambda + \tau * \mu$. Total price which *k*-th consumer may pay to get access to product of a *j*-th company on *i*-th segment at time *t* consists of a price set by firm *j*, costs of joining a market segment *i* ($\mu = 1$), only if consumer hasn't been a subscriber for this market segment in the previous period ($\mu = 0$) and costs of joining a network of a company *j* ($\lambda = 1$), only if consumer hasn't been a subscriber for the products of this company in the previous period ($\lambda = 0$).

In this vision consumer must be well-off initially to become a subscriber because he must have enough money to cover both costs, τ and η, and to be able to pay at least the lowest price set by a company. This state of things may give rise to a phenomenon of market segmentation.

Another thing to mention is that switching between companies within a standard and switching between standards is costly to consumers, which may drag sticky and uneven behaviour of a market.

[1] For instance, to get access to a GSM standard you need to buy a GSM standard cell phone (costs τ) and to subscribe to a services of a given company you need to buy a SIM-card (costs η)

Choice rule

Every consumer has a vector of preferences over a ratio between characteristics of a network service and overall network size. According to these preferences any agents chooses a given service, or product from a set of affordable product which are selected by a participation rule using the following rule:

$\max_{j}\{(\theta_1 \cdot s^j{}_1 + ... + \theta_k \cdot s^j{}_k + \theta_0 \cdot q^j);U\}$, where q^j is network size of a firm j and U is utility from not entering the market.

So, demand for a particular service is formed by its price p_j, network size formed by its subscribers q_j and multidimensional characteristics of the service $S = \{s_1,...,s_k\}$.

Timing of the model

Model functions in a following manner. At time zero initial parameters and sample characteristics are set up and a network market consisting of segments is created. Progression to a following time step occurs within a scheme mentioned below:

1. firms set prices according to their **price-setting rule**;
2. consumers make their choices using their **participation and choice routines**;
3. firms provide consumers with market products relying on their **production rules**;
4. consequences of activities, utilities and profits, are estimated;
5. firms pay interest rates, unsuccessful firms are refinanced and enlarge their debts;
6. firms with positive profits decide to spend its part on search activities using their **search rules**;
7. firms with negative profits shrink in size and lose market positions;
8. search activity breeds results and successful firms decide whether to adopt new product or technology according to their **investment rules**;
9. entry and exit of firms.

Specification of the model for the analysis of cellular telecommunication market in Russia

To build up a good model of a particular market one must first understand the structure of the market, relationships between different parts of a market and subtle feedback mechanisms, which interweave the system under analysis and thus are the essence of the dynamics of that market. Implementing all of this in a theoretical model means walking only a halfway to the final destination of the researcher, whose aim is to understand the flow of the real market development and properties of real system entities interaction and attempt to foresee the events that are going to happen on that real market.

There is no need to concentrate on proving the fact that agents in reality barely act according to the behaviour prescribed to them by theoretical models but conversely, the way they behave in reality must be a key influence on their theoretical interaction within a model. To proceed on these premises we carry on further. We do not only rest upon examination of real data to create a theoretical framework of the model, but we do move further and specify the entities of a model and their characteristics deriving them from empirical data.

We are aware of the facts that limit our goal of full specification of the model. Firstly, some properties of the system are hard to be specified because they are not observable. In this light it is really hard to model preferences of people. People do often make choices that are governed by something different than preferences, something that can be found in the psychological analysis of choice and even when choice is assumed to be the consequence of the attempt to maximize utility these preferences are hidden and not observable. To derive such properties as propensities to innovate, stickiness of consumer's choice, preferences of individuals and many other properties much empirical work must be done. To some extent even the model itself must be rebuilt the way that system properties unobservable in the real world should be substituted for something seen in the reality.

Secondly, the methodology of evolutionary models restricts usage of some types of properties and encourages usage of another ones. We do not argue the bounded rationality acting on behalf of the agents and probabilistic way of choosing behaviour modelled in a Markov chain way. We cannot find empirical evidence to these facts but still we rely on these properties. The same reasoning applies to randomisation processes. Real randomisation rarely is randomisation in its classical sense but rather a consequence of the mental (or even further, sub-conscious) activity at the given moment. The model contains randomisation in a computer sense which is also subject to the way computer works with it.

This paper presents the first step on the way to building a general model with empirical behaviour built into it. Further detailed calibration is the goal of the succeeding papers.

To compute parameters borne to different entities we call to empirical data from different sources, from which the major ones were Russian Statistics Agency bulletins and official reports from Russian cellular telecommunication operators.

The description of the calibrated model for a cellular telecommunication industry in Russia follows below.

Calibration of the model

Market players

To start, let's name model entities. Environment in this model is an artificial market for cellular telecommunication. The market consists of I=3 segments, where each segment is an alternative incompatible with each other technological standard of cellular telecommunication. Within each of the three standards Ji=3 companies provide for similar products that are potentially interchangeable. Total number of consumers that are potentially willing to participate in the market equals 10 000.

Product characteristics

We restrict our attention to a 3-dimentional structure of a cellular technology using which companies produce market services. Let us call them voice transfer characteristic, data transfer characteristic and additional services availability characteristic. These features represent s_1, s_2 and s_3 respectively. It is a clear fact that these technological characteristics are different among technological standards and evaluation of upper bounds of any standard is a subject of empirical work. Basing on different papers we derived the following structure of product characteristics on a cellular telecommunication market[2]. Table 1 presents the abovementioned boundary coefficients for the beginning of the year 2006 with the only exception of the "MSS" company, which left the market in the year 2005.

[2] We used the evaluation method of geometrical distance between innovations introduced by P.-P. Saviotti.

Standard/Company	Voice transfer (s_1)	Data transfer (s_2)	Additional services (s_3)	Average of the three
AMPS (1G)[3]	**0,7**	**0,15**	**0,35**	**0,40**
DAMPS (2G)	**0,9**	**0,5**	**0,7**	**0,7**
Corbina Telecom	0,7	0,15	0,15	0,33
NMT-450 (1,5G)	**0,9**	**0,4**	**0,5**	**0,60**
MSS (year 2003)	0,7	0,15	0,2	0,35
GSM-900/1800 (2G)	**0,9**	**0,5**	**0,7**	**0,70**
MTS	0,85	0,45	0,6	0,63
VympelCom	0,85	0,45	0,6	0,63
Megafon	0,85	0,45	0,6	0,63
CDMA (2,5G)	**1,0**	**0,7**	**0,8**	**0,83**
SkyLink	0,75	0,6	0,4	0,58
UMTS (3G)	**1,0**	**1,0**	**1,0**	**1,00**

Table 1. Product characteristics of cellular telecommunication operators in Russia

In the initial period in the model all companies within a standard have initial conditions drawn from the uniform distribution with the range from zero to the upper boundary of the standard. Of course we do not deny the flow of history and do take into account of the fact that emergence of standards occurred in an arrow of time and potentially superior in terms of technological boundaries standards emerged later in time. To do so we delayed the appearance of newer generation standards for a concrete time interval[4].

The model used calculated boundaries for standards NMT-450, GSM-900/1800 and CDMA. Later standards emerged relatively later than older ones giving time for companies of the relatively more deficient standards to evolve. Initially all companies face the same conditions, and over time they innovate until they reach the technological boundary.

Company identification

Every company faces the same cost function $c=c(q)=931,17\cdot q^{2/3}$, where q is the number of subscribers for the services of a given operator or its network size. This function is the real cost function of the “VympelKom” company. We used primarily this company to estimate production rule because it is the only Russian cellular telecommunication company that has a very long listing history on the NYSE, namely, from year 1996. On average the history tells us that cost functions of other companies may still be slightly different from the one presented above, but the curvature and overall shape are not.

Initial prices set by companies are equal across all of them. Switching costs between companies within a particular standard, η, are equal across companies of that standard and are equal the average price of a SIM-card or any other means of accessing to the network. Joining costs to the standard itself, τ, differ across segments, but still are of the same digit, every one of them averaging the price of a cellular phone of a given standard.

[3] Universally accepted notion of a generation of technology is written in parenthesis.
[4] The calibration of appearance time of a new standard can be made twofold; either by rescaling discrete time intervals or by adjusting the concrete time to historically witnessed development level of older standards.

Let us assume further that every company on the market faces the same search function embodied in its search routine, but still scope to advance network products differs within diverse standards. At this level of research search function is not calibrated because of many difficulties, and is a subject for further research.

All environmental parameters are common knowledge to every company and do not differ among them. Price-setting rule is the same for every company. And its sensitivity to the change in the market share of that company is assumed (theoretically) to be at the level of 0,85.

Consumer identification

Income distribution and income dynamics in the model represent real data in Russia. The closest function representing realistic income distribution is the exponential one: $Y = a \cdot e^{bx}$, where Y – average income of the group, x – income group of population, a – income level of the poorest group and b – inequality coefficient.

According to analysis of the Russian cellular telecommunication market any consumer is ready to spend not more than μ =0,15 share of her income for cellular telecommunication services.

Modelling assumptions tell us that services on the market can be sold only if $P \le \mu \cdot Y = \mu \cdot a \cdot e^{bx}$ holds.

Speculating with terms yields aggregate industry demand as $x = \frac{1}{b}\ln(\mu \cdot a) + \frac{1}{b}\ln P$, where x is the boundary of effective demand for cellular telecommunication services (or all the consumers for whom participation constraints are met). Model extensively uses this demand equation.

Consumer preferences $\theta = \{\theta_1,...,\theta_k\}$ are drawn from a uniform distribution with a mean equal to the average objective service characteristic derived from $S = \{s_1,...,s_k\}$.

In this paper the authors made an attempt at building a model closely approximating reality which is further calibrated to fit real data.

Modelling summary

To analyse results of the model a computer simulation programme has been employed. It generated time series data according to given initial conditions and functioning sequence of the model. The simulations were run under LSD, which is an ideal application dealing with agent-based models similar to the class of Nelson-Winter models and designed by M. Valente.

Complexity of an object under investigation – network market – may give birth to such extremely interesting phenomena and patterns as existence and non-degeneration of competing networks (Arthur 1989, Arthur 1990), domination of potentially ineffective and low-potential technologies (Liebowitz and Margolis 1995) and explosive character of network market development upon achievement of a critical mass point (Economides and Himmelberg 1995). Simulations showed that all of the phenomena pointed out by investigators are present in the evolutionary model of a network market calibrated on real data.

Before proceeding to analysis of results let us claim important feature of the simulations that allows us to consider results as universal. Stochastic character of processes taking place in the dynamics of the model affects individual outcomes of a given time step and forecasting complete model situation is impossible. But still many runs of a model for given initial conditions smoothed out indeterminacy created by individual runs. In a given simulation behaviour and position of a given company could not be forecast, though dynamics and behaviour of a market segment remained more or less stable. Averaging across different simulations helped derive laws and patterns inherent of the network market. It is obvious that results associated with a given company are much more volatile than results obtained for a given market segment.

In this perspective results got after analyzing average time series data are robust which is supported even more after testing the hypothesis that small deviations from initial conditions do not affect resulting outcome.

So, what results have been achieved after the model has been implemented on the computer software? Main modelling results and conclusions are presented below. To make patterns and conclusions derived from simulations more obvious for a reader dynamics of a model from a typical random run is presented on the figures below.

First, the model demonstrates that vitality of inefficient or deficient in terms of potential market segments may arise in equal settings. Path dependence phenomena govern the behaviour of the system and it is the reason why domination of inefficient market segment may be a potential outcome. Path dependence is rooted in two facts: high switching costs or barriers to entry and in positive feedback loop between network size and decision of a new consumer to join the network.

Figure 1 shows dynamics of average quantities of subscribers for 3 segments. Here, 1st segment has the lowest technological ceiling, 3rd segment has the maximum potential of technology.

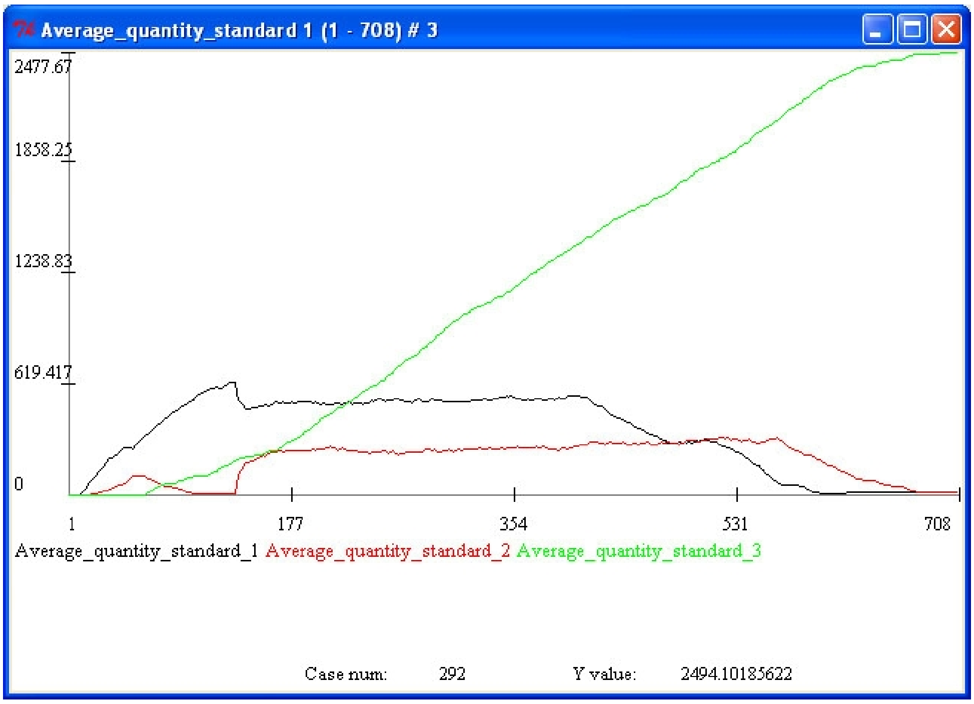

Figure 1. Average number of subscribers for 3 segments

Figure 1 clearly displays that, firstly, inefficient segment has been a dominant segment for no less than 200 time steps, and secondly, that despite the fact that 3rd segment gathered momentum and dominated the market subscriber network for first two segments remained constant.

Hence, we may at best state that potential efficiency of a segment is important only in the long run, when in the short run more important are another segment features such as speed of innovation implementation, search depth among others.

Second, within market segments company shares are subject to high fluctuations and significant uncertainty. If we may state that efficient segment survives in the long run most of the times we may never say the same things regarding the situation of a particular company within a market segment because it has to fight sufficiently hard its rivals and is only protected by its network size. The situation of a company is quite worsened by the fact that barriers protecting the company associated with switching costs of a company are really low. This makes segments much more protected than given companies and their situation much more stable. If innovation by a rival is successful in the sense that it lures critical mass number of subscribers, its further development becomes self-supportive which makes efforts exerted by ex-leader, for example development of new products) to achieve former leading position vain.

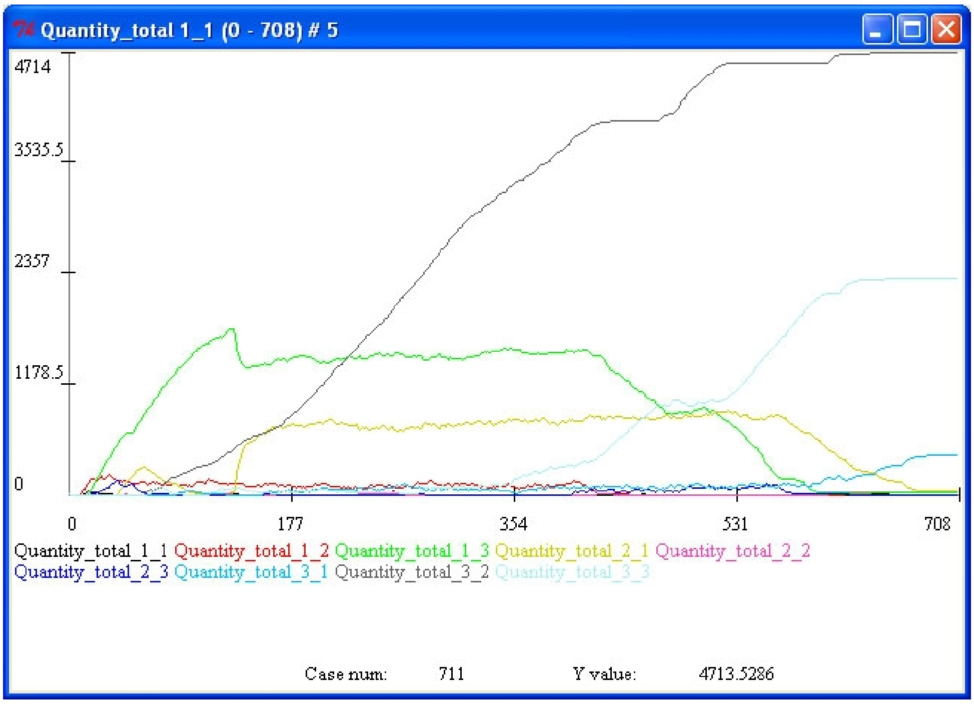

Figure 2. Average number of subscribers for 9 companies

Third, competition between operators is a key force that directs the development of a network market. According to proposed conjectures decrease in the market share of a firm pushes it decrease its prices and new consumers who couldn't join the market before because of their participation constraints can now join the network of the company, which set prices low enough. It shifts ratios of market shares even further and creates incentives for further price-cutting. The same reasoning applies in search activities: application of an innovation by one company makes other firms, who also turned out to be successful, search more intensively, which enables a firm to have an edge over its rivals on the one hand and on the other hand whips up overall quality increase on the network market. Surely these mechanisms only hold until the limits of price-cutting or quality enhancing are not reached.

Fourth, outstanding feature of innovative activity on a network market is the fact that initial conditions do matter whether it'd turn out to be successful or not. On a developing and growing network market more important is not the potential of an innovation but rather speed of its application into a final product and its launching onto the market. As analysis showed in a period of rapid growth of a market more important is the possibility to quickly find and apply an innovation, whether as during stabilisation phase potential of a technology gets the key position in determining the market position of a company. This may be an explanation why inefficient segments may be very persistent and rooted on the network market and why they are developing in a higher pace than efficient segments.

Figure 2 depicts result of simulation where probability of finding a successful innovation increases when potential of a standard decreases. It is clearly seen that during a long time the only companies operating on the market were companies belonging to the least efficient segments. After sufficient amount of time company from the most effective segment couldn't fight companies so deeply rooted on the market and had to cease and leave the market.

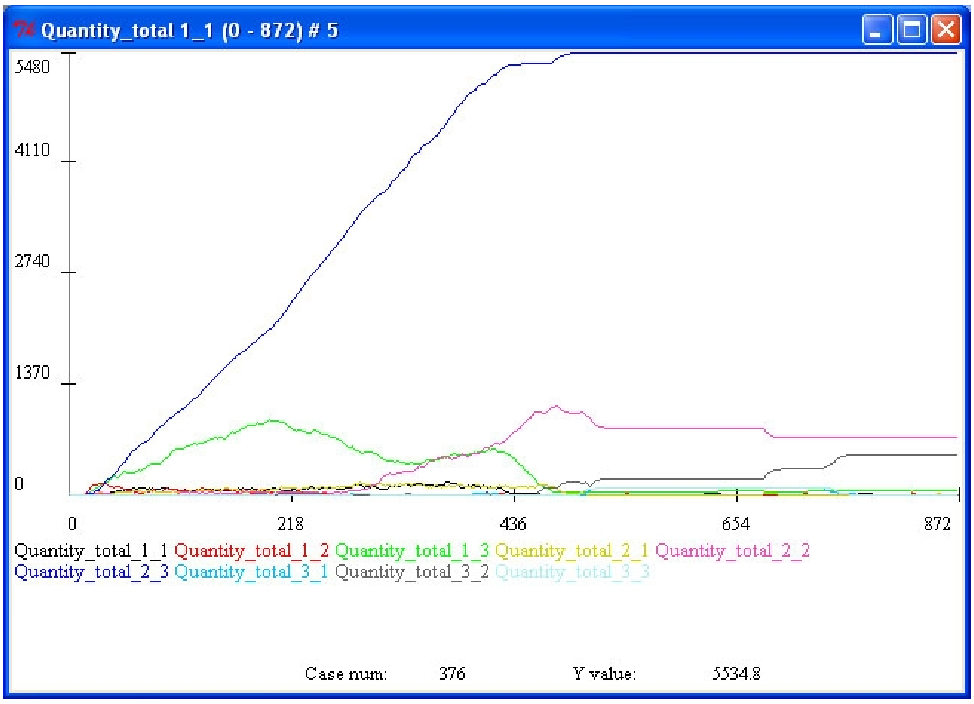

Figure 3. Average number of subscribers for 9 companies

Fifth, on the emerging and developing market concentration index is typically higher than on a developed and stable market. One may claim that development of a market always passes several stages: emergence, rapid growth and stabilization. According to the model concentration of companies peaks during the second phase. To this time most of the unsuccessful companies usually leave because they can't find proper innovations to stand against leaders and the rest of the market evolves actively. Moving to the stabilization stage when no new consumers are willing to join the market, market shares of active companies are becoming to gain stability which forces concentration index to fall as you may see on figure 3.

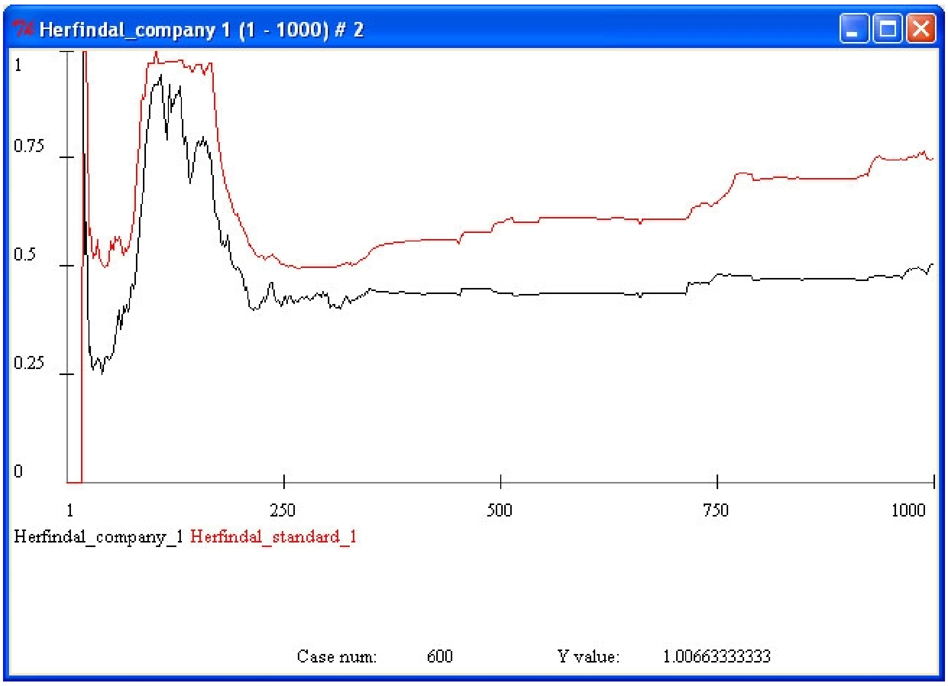

Figure 4. Herfindal-Hirshmann concentration index for companies and segments

Conclusions

In the paper we explored a problem of analysis of network markets with several market segments where each segment can be interpreted as a different technological standard. To describe dynamics of such markets a computer simulation model was employed. The model showed patterns that corresponded to some stylized facts witnessed in the telecommunication industry. These regularities were empirically proved for the Russian market for cellular telecommunication. The major modelling results we found out are the following:

- Inefficient standards in terms of technology may survive (lock-in);

- Several stages for market development were discovered – initial stage, rapid growth and stabilisation. Concentration is the highest on the stage of market rapid growth;

- Firms compete through introducing product innovations, and this type of competition is the source for market development;

- In a developing market with network effects the frequency of innovations is more important for firm performance than the potential superiority of a standard;

- Network markets are found to be very unstable. Any shock on the initial stage may cause a "snowball effect" of new subscriptions or a leakage of consumers from one firm to another (positive feedbacks);

- The disturbance effect caused by the fact of product innovation application on the development of a network market is more significant than the increase in quality dragged by that fact.

The regularities that are born in the model correspond to the patterns that were present in the Russian market for cellular telecommunications and this is seen as another serious argument to back up the choice of a modelling paradigm.

Results achieved in our paper correspond with some conclusions derived by other researchers. On the one hand, the model clearly demonstrates path dependence in the market development. As stated by B. Arthur (Arthur 1989, Arthur 1990) and P. David (David 1985) positive feedback loops breed instability of the system and heavy dependence upon initial conditions.

On the other hand, the model captures the notion of critical mass phenomenon described by N. Economides and others (Economides and Himmelberg 1995, Economides 1996). This feature is a crucial characteristic of every network market. Market for cellular telecommunications surely belongs to the list of such markets.

Finally, our results come in line with models of evolutionary flavour. G. Silverberg, G. Dosi and L. Orsenigo (Silverberg, Dosi and Orsenigo 1988) showed in their model that under some circumstances potential of a new technology is less important than pace of its exploration and speed of its industrial application. In our model firms that explore the technology faster can relatively be at an advantage despite the fact that they work with inferior technology.

This paper represents the first step on the way to establishing a complex model of a network market, which is potentially a subject to further calibration. Many facts have been omitted from analysis and this is a field for further investigation. Both the model framework and the calibration procedure must be changed in a way to fit the analysis of any network market because all of them share many common features. Permanently growing role of these markets in a world economy seriously backs up further papers on these grounds.

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