

FIRM AS A SELF-REPRODUCING SYSTEM

Pavel O. Luksha

Contact Addresses:

Pavel O. Luksha
The Higher School of Economics
Moscow
Pavel.luksha@mstal.ru

May 27, 2003

Proceedings of the 47th Annual Meeting of the International Society for the Systems Sciences,
at Hersonissos, Crete, July 6-11, 2003, <http://www.iss.org>

Copyright 2003 by the International Society for the Systems Sciences (ISSS)

FIRM AS A SELF-REPRODUCING SYSTEM

P. O. Luksha

The Higher School of Economics
Moscow

ABSTRACT

Two generally accepted visions of a firm in economics, the classical (a firm as a profit-maximizing technology-bearer) and the neoclassical (a firm as a set of interdependent contracts to allocate resources) can be amended with a third one, brought forward with a system thinking: a firm is a survivor and thus a self-reproducer. Application of von Neumann's model of universal self-reproducing automate allows to point out that four key elements should exist in a self-reproducing firm: (1) technologies specific to the firm, (2) implementers transforming technologies into actions, (3) tutors, translating technologies to new (and existing) implementers, and (4) a coordinator to ensure consistency and synchronization of these processes. Self-reproduction of firm is one layer between self-reproduction of social individuals and that of a society. An implications of emphasis on firm's self-reproductive function are that a firm should be an efficient social partner, sometimes even at the expense of its profits. It is argued that historically, a transition towards 'self-reproductive' firm is already occurring (as this function is concisely understood), and it appears to be a part of firm natural evolution towards a more complex and more efficient social structure.

APPROACHES TO THE NATURE OF A FIRM

A firm, as a key and universal element of the business world, attracts attention of economic theorists since the emergence of economic science. Still, debates over its structure and functions continue. This paper is to contribute some ideas in a system thinking research of a firm nature.

Two different treatments of a firm should be distinguished: a legal object of property (which can exist virtually as well, e.g. one-day-firms) and a system of human activity, as a way to organize a multiplicity of people. The core interest of this paper is a firm as a 'real organization' that accomplishes a specific set of functions in the economy: an entrepreneurial or corporate enterprise for manufacturing or/and commercial activities.

What is a firm then? Various suggestions have been made, but they all can be reduced to the following statements:

- it is a bearer of technologies that transforms inputs into outputs;
- it is a profit-making engine for capital owners;
- it is a way of resource allocation and interaction in a capitalist economy;
- it is a way of structuring collective cooperative activities of social individuals.

Firm as A Self-Reproducing System

Evidently, each of these points of view can be produced, depending on the aspect of analysis:

1. a technological aspect is a focus on technology in a chain of suppliers and consumers (and a potential profit-making in a sequence of market interactions);
2. an organizational aspect is an emphasis on social relations and interactions in economic sphere (including legal aspect – a firm as a subject of property rights);
3. a social aspect to represent a firm as an element of self-reproduction and self-maintenance processes in a social system.

The first point of view can be attributed to the classic economists (from Adam Smith to Marshall), and it claims that a firm is a kind of “black box” that turns input resources into output products with its technology [Archibald, 1988]. This vision implies that a black box operates better through manufacturing specialization and (thus) economies of scale, main issue being “optimal allocation” of resources. Such approach has logically led to mass production enterprises and a world view now known as Fordism [Aglietta, 1979].

The second one has, as its particular implementation, a ‘Coasian paradigm’ which says that a firm is a way to distribute limited resources alternatively to the market; thus the black box has internal flows of information and interactions between its elements, which may be efficient or inefficient to some criterion (if one compares such interactions to market interactions) (e.g. [Williamson, 1985]). Such vision dominates the business world since early 1970s and it was one of the reasons beyond the restructuring of mass production enterprises (e.g., processes known as outsourcing). This was a significant step in evolution towards ‘network economies’.

A third concept, that can be brought forward within system thinking approach, points out that a firm is a part of a larger system: a society. It is an organized group of people that reproduce specific production activities and their main purpose is not production per se, but a collective sustenance in a capitalistic world. A firm is therefore a ‘survivor’ (this idea is not totally new to economic theory - see e.g. [Malchup, 1967]); it is placed in a network of internal and external relationships (see e.g. [Luksha, 2000]) and must maintain them in order to perform its key functions.

PROCESSES IN A FIRM

Survival traditionally is treated in two aspects. First, the external survival which is briefly described as ‘mitigation of potential disturbance sources’. A survivor is capable to avoid (or protect from) sources of danger and harm, and is also able to ensure inflow of critical resources. In case of economic systems, if a given firm mitigates potential disturbances (e.g. introduction of new standards or intervention of new products) better than its competitors do it will be a better survivor in the market. Second, survival means reduction of internal disturbances, which is known as self-maintenance, and this consequently means reproduction of all necessary components within the same system. Formally, a firm then can be considered a self-reproducer, classified as a semi-self-reproducer that produces parent near replicas [Luksha, 2002b]. A system with such properties, reproducing inside itself, has been coined by

Firm as A Self-Reproducing System

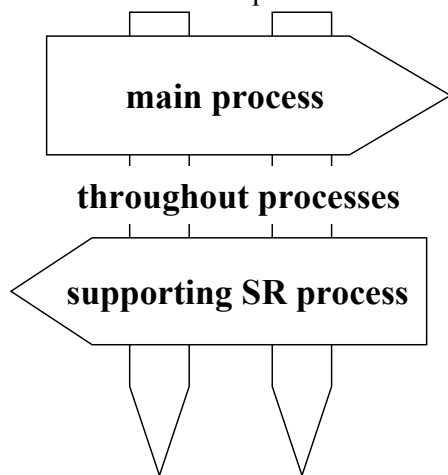
M. Rozov as a ‘kumatoid’, or a wave-like object (see e.g. [Stepin, Gorokhov, Rozov, 1999]).

This position has been first advocated in an evolutionary theory of a firm: firms survive in competition between themselves, and reproduce through reproducing routines, or ‘a typical set of operations’ [Nelson, Winter, 1982]. Like ‘gene war’ or ‘meme war’ suggested by Dawkins as the essence of biological or social evolution [Dawkins, 1989], ‘routine war’ is the essence of competition. Yet, Nelson and Winter do not focus on the reproduction of these routines, associating them with firm technologies. I will argue that this process should be considered in a broader context. Breaking down a firm by its critical components, one may identify reproduction of activities, reproduction of working capital (advancement payments to workers), reproduction of long-term physical capital and of work force. Notably, a firm is not a fully capable self-reproducer, since it depends in this process on inputs produced outside of it: social individuals, technologies, machinery, inputs etc.

A firm is therefore a set of interdependent processes directed towards reproduction of this entity – it is possible to say that a firm is a complex self-reproducer: this idea has been slightly touched in ‘regulation theories’ [Jessop, 1990]; an idea to consider a firm as self-maintaining has also been tried in autopoietic theory [Bednarz, 1988], although only particular aspects of self-maintenance have been considered. An idea that firm tries to mitigate all disturbances has earlier been approached by Stanford Beer, who suggested his notion of ‘cybernetic firm’ that follows a homeostatic principle [Beer, 1988].

However, a key difference of a self-reproducing firm from other cybernetic objects, such as self-reproducing organisms, is that a firm can only exist within the bounds of hierarchically organized social processes. Its main ‘goal of operation’ lies ‘outside’ of itself (a production/trade beneficial to an owner), and a process of self-reproduction is then a ‘supporting’ process. On the opposite, a self-reproduction in biological organisms has a value and a goal in itself. In this sense, a firm is neither ‘autopoietic’ (in terms of theory suggested by Maturana and Varela) nor it is ‘homeostatic’, although it might contain some ‘built-in homeostatic regulators’ that increase its efficiency and accumulate its ‘useful work’ through e.g. repetitions of a firm cycle.

A firm then incorporates several types of processes that go in parallel (see



Firm as A Self-Reproducing System

Figure 1). These processes include:

- a main process (productive or commercial activity that is beneficial);
- a process of self-maintenance and self-reproduction (it is costly in a sense that part of valuable resources is spent to restore initial system properties);
- throughout processes (processes of management regulation and control: finance, administration, IT, legal etc.).

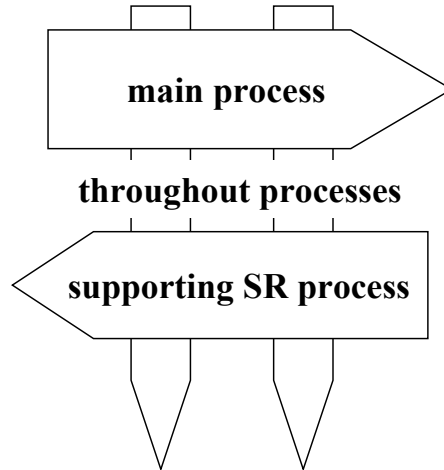


Figure 1. Processes of a firm

A firm then appears to be somewhat similar to an ‘engine’, or a purposefully designed cyclically functioning complex system which accomplishes

- (1) a useful action (or, a target transformation), and
- (2) activities required to restore initial state (i.e. a process of self-maintenance). This process consumes a part of working energy of an ‘engine’; however, without it, a new cycle of activity cannot be started.

It is impossible to achieve 100% efficiency ratio in an engine, since, even in an ideal case of Carnot heat engine with highest efficiency, a part of its energy is used to return engine to its initial state. Similarly, in monetary terms, a part of firm revenue is used compensate suppliers of raw materials, semi-products and services. A firm however also has to restore physical, human and social capital loss (as if an engine would repair itself).

A process of self-maintenance and self-reproduction should not counteract a main process; the opposite is truth as well. Self-reproduction must be implemented in a broader sense: not as only a compensation for inputs, but as a restoration of all long-term resources necessary for system operation.

A PROCESS OF FIRM SELF-REPRODUCTION

Firm as A Self-Reproducing System

To realize the key elements of a firm that support its self-reproduction, theory of self-reproductive automata (see e.g. [Sipper et al., 1998]) can be applied. A basic model of a self-reproducing entity has been suggested by John von Neumann [Burks, von Neumann, 1966]. In his report, von Neumann proposed that a self-reproducing automate must incorporate three key elements:

- (a) instructions that describe a structure and processes of an automate;
- (b) a copying unit, that is capable to read, and copy, instructions: it copies instructions into a new automate, and it translates them as directions for a production unit;
- (c) a factory, or a production unit, that builds a new automate based on incoming instructions.

A fourth (optional) element is necessary to coordinate the other three: a controller, that ensures that both a new automate is build and instructions are copied.

As it has been shown in [Luksha, 2003], this structure (known as JVN automate) is the most universal self-reproducing structure; other simpler structures are possible that can be capable of self-reproduction (on such structure has been suggested in [Laing, 1977], the other is the author's generalization of Eigen's hypercycles [Eigen, Schuster, 1979]).

Yet, an utmost important feature of JVN automate is that it is the simplest structure capable not only reproduce itself, but also to produce arbitrary additional (potentially constructible) components, or to perform arbitrary additional (potentially realizable) operations (unlike other, simpler self-reproducing structures), provided they are described in instructions. This is a direct resemblance of a firm, in which a self-reproduction goes only in support of a 'main' process.

Using the JVN automate model, it is then possible to identify elements that accomplish similar functions in a firm itself. It is evident that a minimal self-reproducing structure of a firm must include:

- (a) technologies (a set of knowledge, skills and codes appropriate for production – this may not be necessarily a formal documented knowledge),
- (b) 'implementers' (laborers or machines transforming a body of technologies into their activities),
- (c) 'tutors' (skilled laborers educating new workers; corporate knowledge databases for self-educations; control centers for replication of machinery codes), and
- (d) a 'controller' (a manager, or an entrepreneur, or a device, that will coordinate activities of implementers and tutors).

Elements of a self-reproducing firm that correspond to units in JVN automate are presented in

	JVN automate	SR firm	Function
1	instructions	technologies	a set of specific knowledge to define a system
2	production unit	implementers	actors that implement a set of instructions in a regularly

Firm as A Self-Reproducing System

			reproduced activities
3	copying unit	tutors	actors ensuring acquisition of key technologies by new implementers
4	controller	coordinator	actor establishing coordination in activities of all other actors to ensure consistency and synchronization

Table 1. Analogies between a JVN automate and a self-reproducing firm

In a contemporary firm, implementers represent the main (working, and supporting) staff of a firm. Technologies there resemble Nelson & Winter's routines (as they include a standard main technological process, and standard supporting processes), but also include standards of corporate identity, known as a 'corporate culture' (even ways to behave at outings).

The function of tutors as a 'copying unit' of a firm is an analogy that can be extended further. It then can be implied that: (1) tutors do not necessarily must remember all instructions, but it is their main function to transfer instructions (stored elsewhere, e.g. in corporate book of standards) to implementers, (2) tutors can transfer instructions to implementers by guiding/controlling them. It then appears that a self-reproducing firm must not necessarily have an institution of tutors; these functions can be handled by a mentoring middle-management, that directs and at the same tutors the main staff of implementers.

Functions of a controller become critical in large organization, where mass-like activities (main process and supporting self-reproduction) take place; there, coordination of activities is taken over by a CEO and other chief officers.

can also describe a firm of the future (such as a self-reproduction plant), as in [Freitas, Gilbreath, 1980] or in [Moore, 1956], since its elements may be not humans and knowledge, but machines and codes.

Because firm is an evolving entity, and a self-reproducer, its evolution mechanics should have resemblances with biological evolution mechanisms. Thus, it may either evolve through internal changes in technologies (mutations in technologies, or selection of best practices), as well as through informational exchange with other firms (recombination, or crossing-over, of technologies). This evolution typically occurs through R&D and internal optimization, but frequently also goes through acquisition of a new staff bringing in new corporate habits and behavioral practices (e.g. in M&A). Evolution of firms is necessary for best firms' selection through market competition, which is studied by evolutionary economics.

Self-reproduction of firms is one possible intermediate layer between reproduction of individuals and that of societies [Luksha, 2002a], and a dominating form of such layer in capitalistic economies. Society self-reproduction requires simultaneous mass-like actions of large groups in populations. On the other hand, a social order does not emerge in itself, as it requires emergence of order on a lower level of organization. Then, social self-reproduction can only be accomplished through 'isles' of organized and manageable economic life: through firms and organizations. If there were only a

system of free economic exchanges in a market, then a contact between each two individuals is only occasional, and links (especially in case of non-specialized goods and services) are not sustainable. In other words, a firm is a 'cell' of social 'macro-organism': only when each cell is self-reproduced, an organism is self-maintained as a whole.

IMPLICATIONS OF FIRM SELF-REPRODUCTION

Realizing the self-reproduction property as a dominating property of a firm may help to shape its practical applications. As social system are self-reflective, a concise understanding of a property in a social system changes a system's behavior towards this property [...]. As shown in Section 1, stages of firm understanding also represent stages of firm evolution.

Two important implications are evident here.

The first one is a changing way to treat human labor. Products in developed countries become more and more knowledge-rich (this means, a growing share of value added is attributed to specific human knowledge and skills), and thus qualified workers become a key and most valuable manufacturing resource (see [Sveiby, 1997]).

Firms can no longer be passive purchasers of 'unskilled' labor produced in households. As they have demand for workforce with specific, even unique, skills, they must ensure that proper qualities are developed in the workforce and further maintained. Firms also tend to compete for the qualified workforce in the labor market, and look for ways to retain qualified workforce (either by bounding contracts, or by stimulation programs). Specialization of firm technologies forces a firm to get involved in personnel development: personnel training, coaching, and building of social capital. This means that firms are forced to become 'self-reproductive' alike. Accordingly, a firm must turn from a selfish profit-maker into a "social partner". Not surprisingly, firms take over some traditionally 'social' functions such as education (social reproduction) and recreation (social self-maintenance) of their employees. Practical examples may include elements of Japanese business model (e.g. lifetime-employment), or business models of transnational consulting companies (such as Accenture, Boston Consulting Group, McKinsey, the Big Four and others).

Another one is a way to organize firms. Business thinking nowadays is still dominated by either classical or Coasian approach, assuming that either scale effect must be achieved (therefore enlarging and specializing) or that efficiency of production should be comparable to market benchmarks (therefore reducing size and outsourcing). It appears that firms 'exploit' human and social capital by letting a society to produce them – much as they exploit natural resources, also produced outside of an economic system.

Consideration of self-reproduction aspect may further adjust business decisions. In modern economies knowledge-rich mass production brings in emergence of long-term links between self-reproducing entities. It has been realized that outsourcing per se is not favorable; companies have to establish long-term non-market relations, and although each of them might have different ownership, they have to coordinate

Firm as A Self-Reproducing System

activities so tightly that in fact they act as a whole. Such cases fall out of institutionalism approach, but they are quite relevant to self-reproduction issue.

Firms may in-source training and recreation, or activities that will be important in the long-term perspective, instead of dropping them out due to short-term benefits. Limits to such in-sourcing will be determined by the ability to remain in the market (e.g. a function of recreation can only be taken over if it is performed more efficiently than in the market). As companies gain wealth through their qualified personnel, they also enter in long-term partnerships with producers of new qualified workforce, such as universities, and institutions for human restoration, such as communities with budget-financed hospitals and cultural institutions, or commercial healthcare / recreation companies.

It also becomes evident that corporate knowledge databases, and corporate trainings, are a critical and a wealth-producing element of a self-reproducing firm. The deposits of firm technologies, and institutionalized ways of translation of these technologies, are both critical for consistent self-reproduction.

SELF-REPRODUCING FIRM: WHAT IS AHEAD?

Elaborating the thesis that major concepts of firm also represent stages of firm evolution, it is possible to bring in the comparison between firm evolution and that of biological organisms. This analogy can also be insightful (Table 2).

Stages of firm evolution	Stages of biological evolution
shop craftsman (full cycle of operations, translation of knowledge to apprentices + transfer of instrument) [before 17-18 century]	a cell (a self-reproduction cycle with self-maintenance and multiplication through division with transfer of all key elements into a new cell)
manufactory (specialization of workers in specific activities, transfer of all knowledge of technology chain through one bearer) [17-19 centuries]	multi-cellar organisms (specialization of cells in specific functions, translation of information through genetic material)
enlargement: giant firms (full-cycle mass-production plants) [end of 19 century. –2 nd half of 20 century]	enlargement: giant organisms (giantism of every kind of biological species was an evolutionary blind-alley)
informational meta-firms (tightly interacting, yet independent, small- and medium-sized firms, which can only be reproduced as unity in close cooperation) [since 1970s]	pre-social organization (interdependent organisms that exist and self-reproduce in tight interactions: semi-reproducers)
«innovation economy» on a society level, based on self-organization principles and transfer to a new level of firm organization [future economy?]	Homo Sapiens society («super-population»)

Table 2. Similarities in biological evolution and evolution of a firm

Firm as A Self-Reproducing System

A predecessor of a contemporary firm can be found in shop manufacturing organization in Middle Ages, when every shop craftsman alone was a bearer of all technologies, accomplishing the full-cycle of operations; similarly, a biological evolution starts with a cell. The development of a firm occurs in 17-18 centuries, with a wide spreading and domination of manufactories, which resemble specialized multicellular organisms (every organ producing specific compounds to be used for collective self-maintenance/ self-reproduction). In 19th-20th century, industries were concentrating and growing, similarly to the biological process of enlargement [...]. In a few last decades, many of such large firms have faced the same problem that any gigantic structure faces: inefficiency. And those which accepted this challenge are now changing.

In the contemporary social organization, a wide-spread formation of self-reproducing mutually dependent chains of firms occur. Such chains can be observed in many industries, and in particular, in those highly advanced such as automotive, aerospace and electronic industries. This process resembles a formation of 'societies', but on the higher level of organization. Such 'societies' may further advance to become a full analog of human super-populations, but on a higher level of organization.

A growing understanding of firms as self-reproducing systems is one good step towards post-Fordistic world where capitalists and workers may become social partners by sharing vision of need to develop mutually and support each other.

REFERENCES

- Aglietta, M. (1979) *A Theory of Capitalist Regulation: The US Experience*. New Left Books, London
- Archibald, G. (1988) *Theory of the firm*. In: *The New Palgrave: A Dictionary of Economics*. 2:357-363. Macmillan, NY.
- Bednarz, J. (1988) *Autopoiesis: The Organizational Closure of Social Systems*. In: *Systems Research*, Vol. 5, no. 1, pp. 57-64.
- Beer, S. (1988) *Brain of the Firm*. 2nd edition. John Wiley Press, London
- Dawkins, R. (1989). *Selfish gene*. Oxford University Press.
- Eigen M., Schuster P. (1979). *Hypercycle*. Springer-Verlag, Berlin.
- Freitas, R., Gilbreath, W. eds. (1980). *Advanced Automation for Space Missions*. Proceedings of the NASA/ASEE Study
- Jessop, B. (1990) *Regulation Theories in Retrospect and Prospect*. In: *Economy and Society*, Vol.19, no.2
- Laing, R. (1977) *Automaton Models of Reproduction by Self-Inspection*. In: *Journal of Theoretical Biology*. 66: 437-456
- Luksha, P. (2000) *Entrepreneur Behavior Efficiency: Further Discussions*. Proceedings of International Conference'00 on Systems Thinking, Innovation, Quality and Entrepreneurship. Maribor, Slovenia
- Luksha, P. (2002a) *Society as a Self-Reproducing System*. In: Journal of Sociocybernetics, Vol.2, no.2, pp. 13-36.
- Luksha, P. (2002b) *Formal Definitions of Self-Reproductive Systems*. Proceedings of 8th Artificial Life World Conference, Sydney, Australia
- Luksha, P. (2003) *Self-Reproduction: Principles of Structure and Operation*. Unpublished report

Firm as A Self-Reproducing System

- Machlup, F. (1967) *Theories of The Firm: Marginalist, Behavioral, Managerial*. American Economic Review, 57:1-33
- Moore, E. (1956) *Artificial Living Plants*. Scientific American, 195:118-126.
- Nelson, R., Winter, S. (1982) *The Evolutionary Theory of Economic Change*. Harvard Univ. Press
- Sipper, M., Tempesti, G., Mange, D., and Sanchez, E. (eds.), (1998). *Artificial Life: Special Issue on Self-Replication*, vol. 4, no. 3.
- Stepin, V., Gorokhov, V., Rozov, M. (in Russian) (1999) *Filosofia Nauki i Tekhniki* (Philosophy of science and technology). Gardariki, Moscow
- Sveiby, K.-E. (1997) *The New Organizational Wealth: Measuring and Managing Knowledge-Based Assets*. Berrett-Koehler Publishers, San Francisco
- Von Neumann, J., Burks, A. (1966). *Theory of Self-Reproducing Automata*. Univ. of Illinois Press.
- Williamson, O. (1985) *The Economic Institutions of Capitalism*. The Free Press, NY