

Effects of the interaction of heterogeneous rationalities on the innovation output of firms - a multi-agent-system approach

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Abstract

Most innovations are the result of contributions from many agents. Not only the firm which eventually commercializes the innovation but also suppliers, service firms, customers, banks, venture capital providers, universities, contract research organizations or technology centres may have participated in this process. Often the collaborating organizations belong to different societal systems like business, science or politics. As a consequence, they face the problem how to deal with the different rationalities of these systems. They have to establish rules and routines how to integrate them in order to avoid conflicts and to benefit from the diversity of rationalities. As far as innovation is concerned there is a lot of evidence that the interaction between different rationalities, especially between the business and science systems, stimulates more advanced or so-called "radical" innovations. Far more ambiguous is the problem of organizing such multi-system based innovation projects. Two basic types of multi-system innovation processes can be distinguished: on the one hand, hybrid organizations which integrate two or more rationalities within the organization and, on the other hand, co-operations and market transactions between single-system based organizations. The aim of the paper is to present the concept of a simple multi-agent system model that simulates the effects of the interaction between the rationalities of the business and science systems on the innovation process of firms and that enables us to compare the two modes of organization - the internal mode of multi-system based hybrid organizations versus the external mode of co-operation or market transaction between single-system based organizations.

1 Introduction

In almost all cases firms are not innovating in an idiosyncratic and isolated way. There is hardly any innovation project without contributions from organizations external to the innovating firm like suppliers, service firms, customers, banks and venture capital providers, universities, contract research organizations or technology centres. Such innovation networks consist of two basic types of social entities: societal systems and organizational systems. Societal systems like business, science or politics are characterized by specific rationalities which comprise values, meaning, and communication modes that are shared throughout the community of individuals involved in these systems and that are typical only for this system. Societal systems are evolving by ways of self-organization. Organizational systems, on the other hand, like firms, universities, public administration or technology centres are characterized by specific rules and routines, stated objectives, resources and formal membership. From this theoretical point of view, an innovation network consists of a multitude of several societal systems and their interrelations. Organizational systems are usually either interacting with organizations belonging to other societal systems or are themselves involved in more than one societal system. As a consequence, they face the problem how to deal with the different rationalities of these systems. They have to establish rules and routines how to integrate them in order to avoid conflicts and to benefit from the diversity of rationalities. As far as innovation is concerned there is a lot of evidence that the interaction between different rationalities, especially between the business and science systems, stimulates more advanced or so-called "radical" innovations. Far more ambiguous is the problem of organizing such multi-system based innovation projects. Two basic types of multi-system innovation processes can be distinguished: on the one hand, hybrid organizations which integrate two or more rationalities within the organization and, on the other hand, co-operations and market transactions between single-system based organizations. The aim of the paper is to present the concept of a simple multi-agent system model that simulates the effects of the interaction between the rationalities of the business and science systems on the innovation process of firms and that enables us to compare the two modes of organization - the internal mode of multi-system based hybrid organizations versus the external mode of co-operation or market transaction between single-system based organizations.

2 On the correlation between innovativeness and border-crossing between societal systems

In the course of a large European research project, investigating and comparing innovation systems at the regional level (1), we became interested in the more basic question concerning

the nature of innovation systems. What type of system is this? What are the constituting elements? Are there subsystems? This has been discussed in more detail in Kaufmann, Tödting (2001). In this paper I am going to highlight only the most important arguments and results.

In modern social systems theory, the concept of 'self-referential' systems has become very influential. In short, it means that the behaviour of a social system is independent in interpreting external influences, organizing its internal structure, and behaving in the context of its environment. External stimuli cannot determine the system's responses. Insofar, the system is closed. Nevertheless, it interacts in numerous ways with its environment, using as well as providing resources and information. In this respect, the system is open. As a consequence, the environment restricts the set of alternatives of any system. Ultimately it may even destroy the system, but it can never control its behaviour.

In social systems theory there is an increasing interest in systems concepts based on self-reference and self-organization. Social systems are seen now as a way to reduce the complexity of the world human beings are confronted with. The reality an individual has to cope with is less complex within a system, because it can and must use the common set of interpretations concerning the part of reality which is relevant for the system. The interpretations are valid for all members of the system which, on the one hand, reduces ambiguity, but on the other hand, restricts alternative interpretations of the system-specific reality (Willke, 1993).

It was primarily Luhmann (1991, 1996) who tried to understand how social systems separate themselves from the environment, how they maintain a boundary between their entity and the surrounding world. He argued that the identity of a certain social system is given by a common standard of communication both to interpret internal processes and external relations to the environment. This makes a social system distinct from its environment and other systems. Accordingly, any social system is distinguishable by different modes of interpretation, decision rules, objectives, and specific communicative standards (channels, methods, technical means, and so on). The common understanding of activities within the system, of influences on the system, and of behaviour against the environment separates the system from the environment. Communication is reproduced through the continuous process of sending or disseminating and processing relevant information. The central mechanism to separate system-relevant from irrelevant information is a system-specific medium (the most often quoted example is 'money' for the business system). It contains only the system-specific information and it is coded in an unambiguous way so that it is understood by all individuals involved in the system. This enables a continuous chain of communication relations and, as a consequence, the continuous reproduction of the social system.

It is important not to confuse systems and organizations. Here the term 'system' is applied to entities based on common standards of communication and information, a common set of interpretations, and a shared view of values and meaning ('*Sinn*'). An 'organization', on the contrary, refers to entities which are based on membership, specific tasks of the members (participants), certain methods to perform these tasks, explicit and impersonal rules, power to enforce the rules, and a formalized structure (Reinhold et al., 1992). From this clarification follows that any individual is involved in several systemic contexts performing as many roles. As far as organizations are concerned, relations to more than one system are not necessary, but, actually, organizations linked to several systems are more the rule than the exception.

From the perspective of the self-referential model of social systems there is not one coherent innovation system but, on the contrary, several social systems are involved in the process of innovation. A single innovation system would have to have common sets of interpretations, the same decision rules, shared objectives, and identical ways of communication. Due to the fact, however, that there are very diverse actors taking part in the process of innovation - clearly reaching beyond industry - such a level of concurrence does not exist. There are important non-business and non-profit elements in many innovation projects, in particular science and politics. The business system is profit-oriented and communicates via the price mechanism; the science system aims at the production of knowledge and communicates via publications. It is the exchange of formerly unrelated information belonging to a different systemic context that reinforces innovativeness. Crossing the border between different systems stimulates changes in the systems in general. In the particular case of industry-science interaction this might, among other things, result in product innovation.

It is very important to distinguish the relation between systems from the relation between or within organizations. The science and the business systems are based on different modes of interpretation, decision rules, objectives, and ways of communication. There is no overlapping of the systems, but there is interaction between the systems, either within one organization or between several organizations. This difference is rarely considered when arguing for the emergence of a new form of science - the so-called "entrepreneurial science" as a new type of science-industry interaction (Etzkowitz et al., 2000). The concepts 'system' and 'organization' are confused, neglecting the fact that it is the clear distinction between the two ideal types of organizations 'university' and 'firm' which gets more and more blurred through profit-oriented contract research institutions, but not the distinction between the systems' operating principles.

From the perspective of self-referential systems theory the major impulse from the science system to initiate innovation in the business system is either due to the provision of new information, not accessible or available within industry, or the collaborative generation of new knowledge. Co-operation can also trigger the change of traditional perspectives, decision

rules, and objectives of firms without actually adding knowledge. Inter-system communication can raise interest to discuss the objectives per se or their practical usefulness, i.e., an appropriate relation between objectives and results. Changes can be stimulated also in technical and organizational respects. Of course, all this is not restricted to one participating organization - the firm - only. It is obvious that interaction between science and industry also stimulates change in universities and research organizations. In any case, the stimulating effect is eventually a consequence of adding novelty and diversity to a specific organization's rules, modes of behaviour, and technologies.

The process of systems mutually influencing each other but maintaining their separate entity throughout this process can be called 'border-crossing'. Of course, interaction between different systems can also become routinized. In the context of innovation this might reduce the potential to stimulate change. This is a likely consequence of continuous relations between the same persons over a long period of time, because the novelty of exchanged information usually decreases once partners become locked into well-established routine interactions. It follows that interaction between science and industry per se is not a guarantee for increased innovativeness. Routine relations like testing performed by research laboratories on behalf of firms do not add much to the firms' capacity to innovate. Also in the case of inter-system innovation partnerships the organizational relations have to be kept flexible through weak ties to a broad range of innovation partners (Granovetter, 1973; Grabher, 1993; Meyer-Krahmer and Schmoch, 1998).

That the interaction between the worlds of science and business matters with regard to innovative performance was also confirmed by empirical evidence deduced from data collected in the REGIS-research project (1). Using survey data for Wales (UK), Wallonia (Belgium), Baden-Württemberg (Germany), Styria (Austria), the Basque country (Spain), Aveiro (Portugal), and Tampere (Finland), the hypothesis was tested that firms which involve partners from science in their innovation processes are more likely to be able to realize more advanced innovations (i.e. develop products that are new to the market) instead of innovations which are only new for the firm. Accordingly, partners from the business system were expected to be more relevant for incremental innovation (Kaufmann, Tödting, 2001).

Table 1: The importance of partners and firm characteristics on innovativeness

<i>Binary Logit model</i>	<i>Products new to the market versus products new for the firm only</i>		
	β	Probability	Significance
Innovation partners:			
Customer firms	-0.262	0.247	
Supplier firms	0.908	0.014	**
Consultants	1.225	0.016	**
Technology transfer organizations	-0.541	0.230	
Contract research organizations	-0.483	0.222	
Universities	0.994	0.047	**
Characteristics of the firms:			
Employment	0.000	0.155	
Region:			
Austria (Styria)	-1.215	0.036	**
Belgium (Wallonia)	-0.891	0.054	*
Finland (Tampere)	-2.040	0.000	***
Spain (Basque country)	-2.839	0.000	***
UK (Wales)	-0.908	0.052	*
Portugal (Aveiro)	-1.716	0.009	***
Industry:			
Food, beverages	-0.260	0.340	
Textiles, clothes, leather	-0.791	0.131	
Wood (products), paper	0.579	0.191	
Chemicals, rubber, plastic	-0.277	0.285	
Metal, metal products	0.122	0.399	
Machinery	-0.414	0.203	
Other industries	-0.265	0.344	
Transport equipment	-0.167	0.389	
Producer services	0.018	0.486	
Model significance:			
Number of cases		318	
r^2		0.164	
r^2 corr.		0.060	

Source: REGIS-survey 1996 (1) (Kaufmann, Tödting, 2001).

As far as the aim of this paper is concerned, the following conclusions are important (see the grey lines in table 1): Universities stimulate or enable firms to introduce more advanced innovations whereas contract research organizations have no positive effects in this respect. "Pure" science seems to be more effective in stimulating advanced innovations than applied research focusing on commercialization. Institutions particularly designed to act as intermediaries between science and industry like technology transfer organizations do not seem to be effective in stimulating advanced innovations.

It can be seen that science-business interaction matters as far as more advanced innovations are concerned, but it is an open question how to organize this interaction effectively. Are market transactions sufficient or are co-operations between organizations involved in both the science and business systems better? Or should both systems' rationalities be integrated within one (so-called "hybrid") organization?

The open question of the adequate organization of science-business interaction was the motivation for developing the model outlined in this paper.

3 A general multi-system agent-based microeconomic model of socio-economic evolution

3.1 Agent

Any agent, individual person as well as organization, is defined by a set of objectives (O), routines (E, V, U), resources (R) and his address (L): $\{O, \{E, V, U\}, R, L\}$.

3.1.1 Objective

Objectives (O) consist of a stated goal (g) and either discrete or continuous target values (v). There are societal and organizational goals.

- Societal goals are shared within societal systems and differ between them. The target values, however, are not identical within societal systems.
- Organizational goals are stated by organizations. They are only valid within these organizations which means that they matter for those persons who are members of the respective organization.

3.1.2 Routine

Routines, in general, take the form of if-then rules consisting of the function (f) and parameters or weights (p). There are three basic types of routines which are necessary for any agent with learning capability (the only type of agent considered in this model). This set of routines comprises routines for expectation, evaluation and update. If all types of routines are present, the set is complete, in case of incomplete sets, routines for evaluation or update are missing.

- Expectation routines (E) consist of rules how the environment (or specific parts of it) will behave or change in a certain period of time and how own actions affect the environment.
- Evaluation routines (V) are rules how to compare realized effects with stated targets.
- Update routines (U) are rules where to search for new routines and how to update the old routines whose performance were deemed unsatisfactory.

3.1.3 Resource

Resources (R) comprise production factors other than manpower (human capital embodied in individual routines), i.e. financial and physical capital (buildings, machinery, materials), technology (disembodied knowledge) and other immaterial capital (e.g. copyrights).

3.1.4 Address

The address of an agent (L) contains his name and may contain, in case the spatial dimension of the network matters, his physical location.

3.2 Action

Any action (A) of an agent is the result of the application of a certain routine on specific resources available to the agent at this time. Corresponding to the three types of rules, there are three types of actions: $A = E(R)$, $A = V(O,R)$, $A = U(E,V,U)$. Actions can be external (global as well as directed) and reflexive. External actions aim at the environment (including other individuals and/or organizations). The action can either be global: $A(x_1 \rightarrow Env)$. Or it can be directed towards certain other agents: $(Ax_1 \rightarrow x_2)$. Reflexive actions like updating rules refer to the agent himself: $A(x_1 \rightarrow x_1)$.

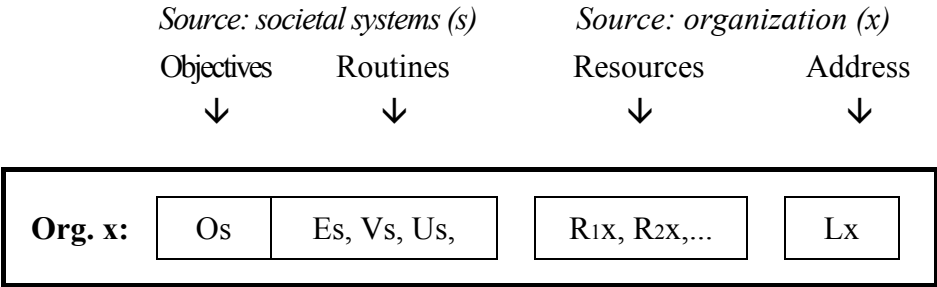
3.3 Organization

An organization is the structured set of inter-individual relations governed by organization-specific routines. Individuals and suborganizations are restricted regarding their set of possible actions (applicable routines) as far as they are members of the organization. On the one hand, only a fraction of their resources can be employed in the organization's context; on the other hand, resources beyond a member but within the stock of the organization may be made accessible by certain organizational routines.

Organizations need internal as well as external routines:

- Internal routines govern specification (functions, restricted set of actions) and duration (one-time, limited, unlimited period) of relations between members of the organization.
- External routines govern relations with the organization's environment.

Chart 1: Formal description of an organization



Thus an agent x is defined by the following set of variables:

$$\{Os, \{Es, Vs, Us\}, \{ R1x, R2x, \dots \}, Lx\}$$

The new organization-specific routines can either belong to one of the societal systems of its members or belong to another system or even found a new system. The latter case is not considered in the present model.

3.4 Societal systems: the global pool of routines

Each routine of an individual or an organization is "stored" in respective societal systems. Any routine belongs to a specific societal objective and is stored in the corresponding system. If they belong to the same objective, both routines used by individuals and organizations, are added to the specific system's pool of routines.

Each routine is represented regarding the function as well as the parameters. Routines are represented according to their frequency, i.e. the number of agents (organizations) applying these routines. As a consequence, the more agents represent a certain routine, the higher is the probability that this kind of routine will be chosen by organizations looking for a better alternative.

If an agent looks for new routines because the old ones have been found inadequate, he does not necessarily choose only according to frequency (the more often a certain routine is represented, the more likely it will be adopted), but possibly also to proximity (the smaller the

difference between old and new routine, the more likely it will be adopted) or other self-formulated rules.

3.5 Evolution

Evolution in a socio-economic context means the emergence of new and the change of existing organizations which is equivalent to the change of an organization's set of routines. As a consequence, the basic elements of evolution are routines, the entities of evolution are organizations. Two major evolutionary processes can be discerned:

Emergence of new and death of organizations

- Change of routines in an organization which maintains its entity.
- Emergence of new and death of old organizations.

3.5.1 Change of routines

There are two possible causes why routines are changed:

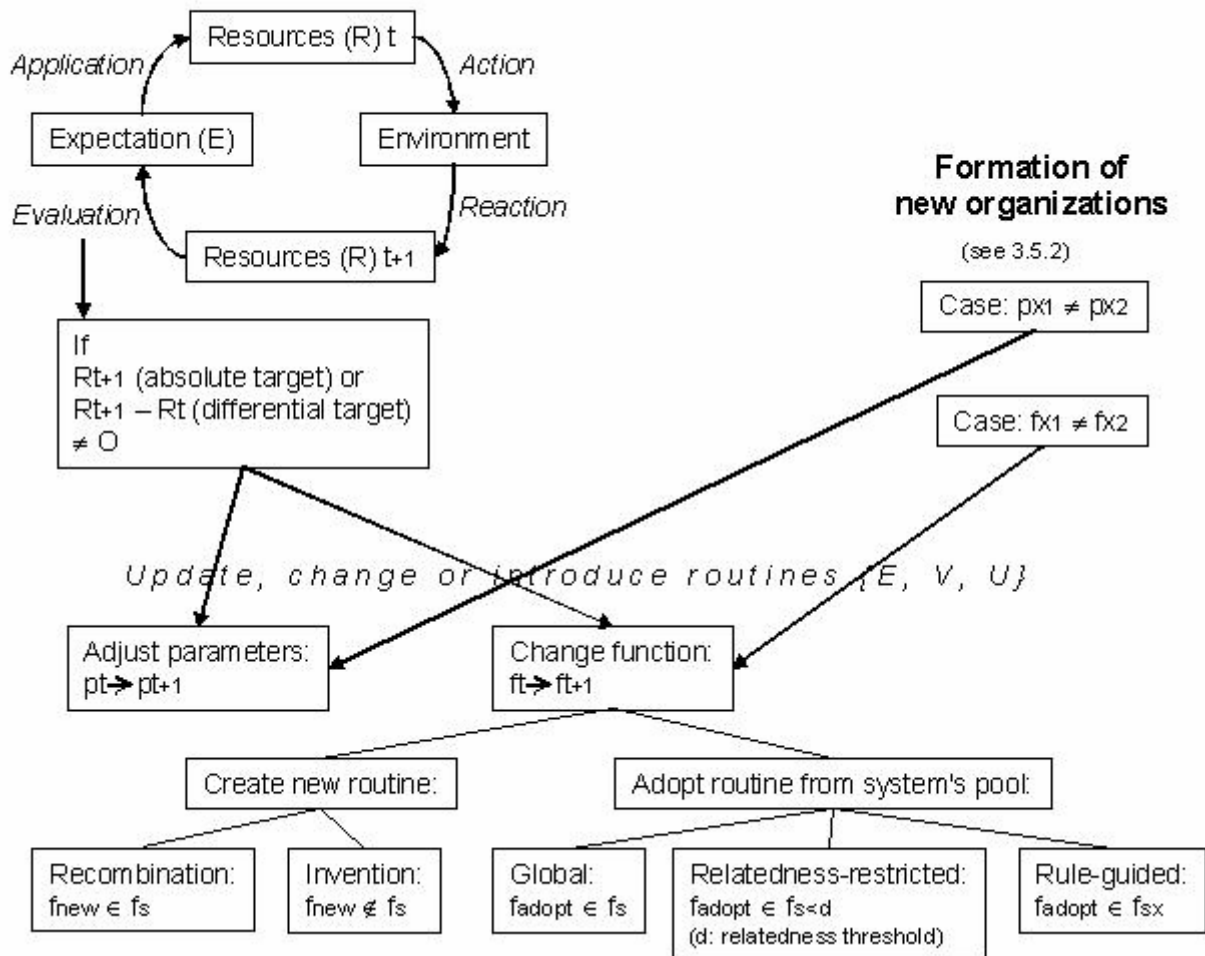
- If the evaluation of a certain routine (more precisely, the executed action resulting from the application of this routine) is deemed unsatisfactory, the update rule is invoked and leads to a change in routine parameters or the search of new routines.
- In the process of setting up a new organization, new routines might become necessary (see 3.5.2).

In both cases routines may be adopted or created:

- In the case of adoption, the pool of routines sharing the same objectives (i.e. belonging to the same societal system) is scanned and from this pool a new one is adopted, either globally by chance, restricted by proximity or according to a special condition of the update rule.
- New routines may be created either by recombining parts of existing routines or from scratch (i.e. unrelated to any existing routine). The latter case cannot be modelled (beyond random processes) and have to be given exogenously.

Chart 2: Adjustment, change and introduction of routines

New routines in established organizations



Concerning the societal acceptability of newly created routines, the minimum condition is that objectives remain the same (the evolution of societal objectives is beyond the described model). Further restrictions are possible, e.g. thresholds regarding to what degree of novelty (or degree of unrelatedness) the proposed new routine will be accepted within the societal system.

3.5.2 Development of organizations

Organizations are founded if individual persons or organizations expect to achieve a goal better (or only) in case they join with other agents forming a new (higher-level) organization. If this expectation is shared by other agents, the new organization will be established. For that routines have to be integrated (excluding ineligible individual routines, aligning useful individual routines) and, finally, the organization-specific set of routines has to be established. As a consequence of this final step, the original organizations dissolve. This concerns the organizational entity, but not the systemic routines. The latter ones evolve in an independent way, influenced by but not tied to the development of certain organizations.

Chart 3: The process of establishing a new organization

Situation at t_0 : Two organizations, each involved in one societal system only:

$$x_1: \{Os_1, \{Es_1, Vs_1, Us_1\}, \{R_{1x_1}, R_{2x_1}\}, L_{x_1}\}$$

$$x_2: \{Os_2, \{Es_2, Vs_2, Us_2\}, \{R_{1x_2}, R_{2x_2}\}, L_{x_2}\}$$

\Rightarrow Both organizations expect better goal achievement in case they join than in case they stay independent:

$$Ex_1: O(x_1 + x_2) > O(x_1)$$

$$Ex_2: O(x_2 + x_1) > O(x_2)$$

\Rightarrow The additional benefit from joining can be due to:

1 Pooling resources: ($R_{x_1} + R_{x_2}$)	1.1 Market transaction:	Unilateral relation (i.e. the partners exchange different types of contributions (e.g. money against goods), one-time relation).
	1.2 Co-operation:	Bilateral relation (i.e. the partners exchange the same type of contribution (e.g. knowledge), limited period of time).
2 Integrating routines: ($\{E, V, U\}_{x_1} + \{E, V, U\}_{x_2}$)	Hybrid organization:	New organization, unlimited period of time.

\Rightarrow In case of integrating routines (alternative 2), each partner's routines have to be matched in order to establish a new organization:

"Merger matrix"		x_1			
		E	V	U	
	x_2	E			
		V			
U					

<i>If for a routine</i>	<i>then</i>
$(f,p)_{x_1} = (f,p)_{x_2}$	reduce routines
$fx_1 = fx_2, px_1 \neq px_2$	align parameters
$fx_1 \neq fx_2$	find new routine

\Rightarrow Establishment of a new organization:

$$x_3: \{Os^*, \{Es^*, Vs^*, Us^*\}, \{R_{1x_1}, R_{1x_2}, R_{2x_1}, R_{2x_2}\}, L_{x_3}\}$$

The new organization can, but need not, be characterized by a new objective:

1 Single-rationality fusion:	$Os_1 + Os_1 \rightarrow Os_1$	(impossible in this example)
2 Multi-rationality "take-over":	$Os_1 + Os_2 \rightarrow Os_1$	(possible)
3 Emergence of a new rationality:	$Os_1 + Os_2 \rightarrow Os_3$	(possible)

\Rightarrow Development or emergence of new routines and feeding back new routines to societal systems: see chart 2.

4 The innovation model

4.1 Innovation

Product and technological (or process) innovations are both results of and driving factors in socio-economic evolution, but they are neither the elements nor the entities. They are the results from actions based on the application of routines and they are, in turn, resources at the disposal of the innovating or another benefiting agent.

Two levels of innovations are considered in the model:

- Incremental innovations: These are products which are new in the respective firm's product range but have to compete with similar products (fulfilling the same functions or providing the same services) offered by other firms.
- Radical innovations: These are products which are new to the market. There are no competing firms or products available at the time of the introduction. The innovative firm has a temporary monopoly.

4.2 The societal systems

Two societal systems are considered in the model: business and science. Other systems with potentially high influence on innovation like politics are not included in the model at this stage.

Objectives and routines are still extremely simplified in this first model. The set of objectives and, in particular, routines can and will become much more diversified as the model is going to be improved.

4.2.1 Objectives

In both societal systems considered in this model - business and science - there exists only a single objective (see table 2). This system-specific homogeneity concerns only the goal but not the target values (see 3.1.1).

Table 2: Objectives of the societal systems 'business' and 'science'

	<i>Business system</i>	<i>Science system</i>
Objective (O, g):	Achieve profit target v : Sales - (production costs + innovation costs) $\rightarrow v$ (sales = price * market share)	Production of new knowledge: Number of articles in science journals $\rightarrow v$

In the current model there is no third category of objectives. This is not only due to the fact that at present only two societal systems are considered, but also that for the time being the emergence of a new societal system out of the sector of hybrid organizations is ruled out.

4.2.2 Routines

Table 3: Routines of the societal systems 'business' and 'science'

	<i>Business system</i>	<i>Science system</i>
Expectation (E, f):	a) Market development: Models estimating future demand (e.g. linear, exponential, logistic, conditional) b) Likelihood of innovation's success: b1) Models assessing the expected return on isolated innovation activities (without science participation) b2) Models assessing the expected return on joint innovation activities with science: - by market transaction - by co-operation - by setting up a hybrid org.	Likelihood of research results being published in a science journal: 1) Models assessing the expected return on isolated research activities (without business participation) 2) Models assessing the expected return on joint innovation activities with business: - by market transaction - by co-operation - by setting up a hybrid org.
Evaluation (V, f):	Targeted profit (v) - realized profit, with or without minimum difference for applying U	Targeted number of articles (v) - realized number of articles, with or without minimum difference for applying U
Update (U, f):	E.g. if targeted > realized profit by less than x%, then reduce profit target to realized level; if targeted > realized profit by x% or more, then look for new E; if else, no change	E.g. if targeted > realized number of articles by less than x%, then reduce target value to realized level; if targeted > realized number by x% or more, then look for new E; if else, no change

4.3 The actors

The model consists of two basic and one emergent types of organizational actors:

- Firm (x_B): This is a single-rationality organization, exclusively involved in the business societal system. A firm has only business objectives and routines.
- University department (x_S): This is the other single-rationality organization, exclusively involved in the science societal system. A university department has only science objectives and routines.
- Hybrid organization (x_H): This is an organization which integrates the business and science rationalities in its objectives and routines in order to benefit from the combination of both rationalities. Routines may be combined in order to be applicable both for business and science objectives or it can be specified under which conditions a certain routine of a certain system will be applied.

The population comprises the following categories of agents:

- innovative firms without involvement of science (radical, incremental),
- innovative firms with involvement of science (radical, incremental),
- university departments involved in business innovation,
- university departments without links to firms,
- innovative hybrid organizations (radical, incremental),
- non-innovative firms

The resources that are available to the three types of agents are:

- For firms: production capital, innovation knowledge
- For science organizations: research personnel, research knowledge
- For hybrid organizations: production capital, research personnel, innovation / research knowledge

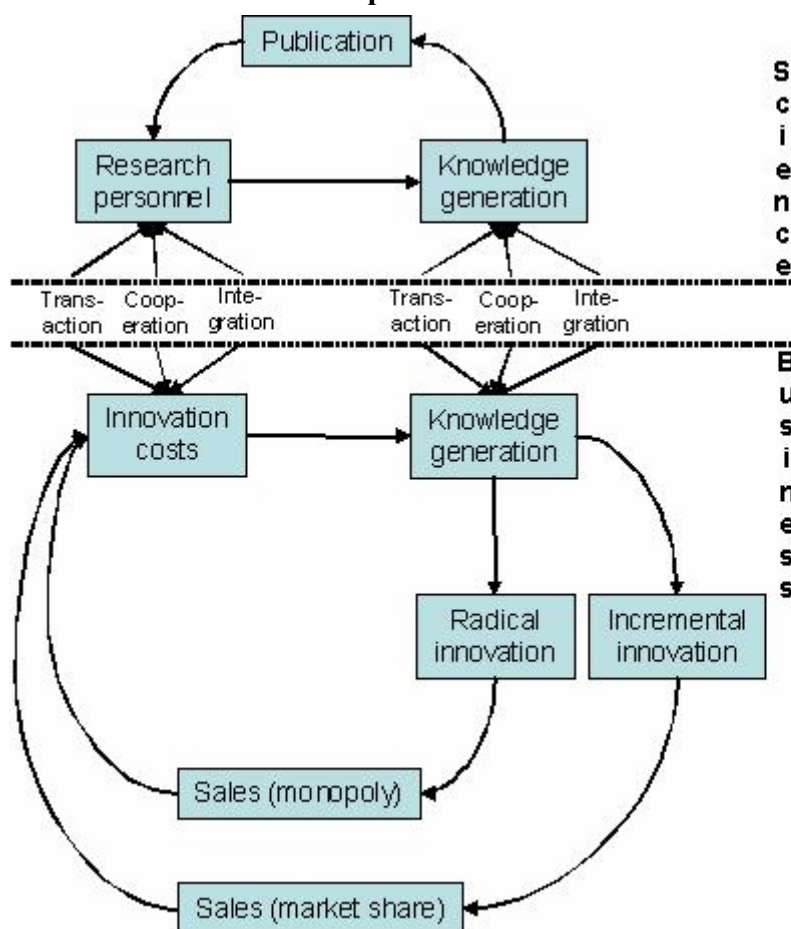
4.4 The interrelation between inter-system collaboration and innovativeness

The model consists of three feedback loops:

- The business cycle: Radical innovations lead to a temporary monopoly (i.e. a market share of 100%), incremental innovations increase the market share. Both types of innovations require funds and cause costs. Firms which do not innovate lose market share compared with innovators but can produce cheaper because they do not have innovation costs.

- The science cycle: The higher the funds available for research and the broader the knowledge (positively correlated with the number of science-business projects), the more articles in scientific journals can be produced.
- The interrelation between the business and science cycles: Business-science innovation projects are more likely radical than incremental. The probability of an radical innovation and innovation costs depend on the type of organization. Pure business innovation projects are more likely incremental than radical. On the other hand, science-business innovation projects lead to more funds which means more research personnel as well as new knowledge too which, in turn, increases the number of publications.

Chart 4: The feedback loops in the business-science innovation model



4.5 Types of organizing business-science interaction

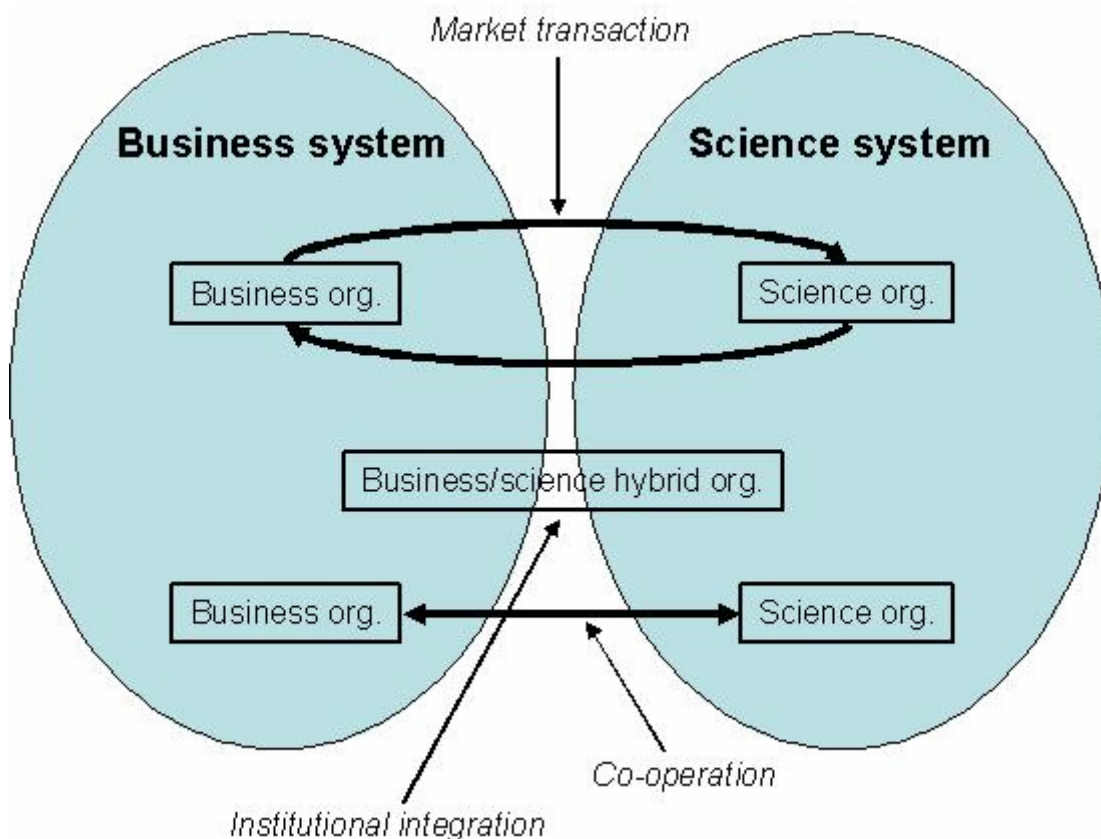
In the present model three basic types of organizing the collaboration between the worlds of business and science will be considered:

- Market transaction between single-rationality organizations: This type refers to a remunerated contribution (e.g., developing components, testing) of a certain organization

(e.g., a manufacturing firm, a firm offering engineering services, a university department) to the innovation project of another organization based on an exact specification without further co-operation.

- Co-operation between single-rationality organizations: In this case two or more organizations establish a joint innovation project, sharing the same objective, pooling their resources, exchanging knowledge and producing new knowledge. The co-operation is limited for the time necessary to finish the project (or a specified range of projects).
- Hybrid organization integrating business and science rationalities: Here the business and science rationalities are integrated within a single institutional framework without temporal limitation.

Chart 5: Three basic types of organizing business-science innovation collaboration



These basic types of organizing the innovation-related interaction between the societal systems of business and science have two consequences:

- Firstly, they lead to different effects on the innovation process and the final outcome.
- Secondly, they cause costs of different magnitudes.

Table 4: Effects of different types of organizing joint innovation projects on business and science

	<i>Business</i>	<i>Science</i>
Market transaction:	XB: Receipt of a specific component or service for the innovation project without exchange or joint production of knowledge → Increase in likelihood of successful incremental innovation	XS: Receipt of payments without gaining new knowledge (beyond the specification concerning the contribution required) → Funds for additional research personnel
Co-operation:	XB: Exchange and joint production of knowledge → Strong increase in likelihood of successful incremental innovation, increase in likelihood of successful radical innovation	XS: Exchange and joint production of knowledge → Strong increase in likelihood of successful publication
Hybrid organization:	XH: Exchange and joint production of knowledge → Increase in likelihood of successful incremental and radical innovation	XH: Exchange and joint production of knowledge → Increase in likelihood of successful publication

XB: firm, XS: university department, XH: hybrid organization

Table 4 presents some effects of the organizational alternatives on the firms' innovation and the science organizations' research performance. In the case of the first two types the effects concern separate organizational entities, in the case of the third type, the effects occur in a single entity - the hybrid organization. The effects described in table 4 are only a preliminary extremely simplified selection. They have to be refined in the future versions of the model. Table 5 shows, in a corresponding way, the costs related to the three alternatives.

Table 5: Costs of different types of organizing joint innovation projects for business and science

	<i>Business</i>	<i>Science</i>
Market transaction:	XB: Price of the component or service → Small increase in costs of innovation	XS: None
Co-operation:	XB: Costs of setting up and organizing the co-operation → Strong increase in costs of innovation	XS: Costs of setting up and organizing the co-operation → Increase in costs of publication
Hybrid organization:	XH: Costs of integrating both rationalities in one organization → Increase in costs of innovation	XH: Costs of integrating both rationalities in one organization → Increase in costs of publication

XB: firm, XS: university department, XH: hybrid organization

5 Outlook

The innovation model presented in this paper is still preliminary. A lot of work has to be done before a model will be available which is adequate to make for interesting simulation results. What are the next steps?

- Empirical work has to be conducted concerning the routines in business, science and hybrid organizations that are actually used as far as innovation and R&D is concerned.
- Important issues are not yet included in the model. This concerns in particular the most basic agent and evolutionary processes. In the present model all agents are organizations, there is no agent 'individual person'. This is not satisfactory in two respects: Firstly, with the present model it is not possible to simulate the emergence of primary organizations, set up by individual people. Secondly, the model lacks the crucial role of people who are actually linking societal and organizational systems. Regarding evolutionary processes, much richer models of recombination and creation of new routines are required than those available at the moment.
- The simulation program has to be developed. This will be done at ARC / Systems Research, probably in co-operation with the Dipartimento di Informatica, Sistemistica e Comunicazione, Universita di Milano-Bicocca. At this institute a software for simulating multi-agent systems - L*MASS (Bandini et al.) - has been developed which seems very appropriate for the requirements of the model presented above.

- Finally, objectives and routines actually used in the real world have to be formalized according to the model requirements.

Running the final simulation model should enable us to compare the advantages and disadvantages of the three alternative ways of organizing innovation activities involving both business and science societal systems. This should make it possible to arrive at conclusions about the rationale and the potential of hybrid organizations in joint business-science innovation processes.

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