MODELLING INNOVATION DYNAMICS BY USING SYSTEM DYNAMICS METHODOLOGY

by

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SYSTEM DYNAMICS METHODOLOGY

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Abstract

The topic of this study is the investigation of the innovation strategies from the perspective of a durable household goods manufacturer. Although the durable household goods industry is designated as a mature industry, still there is extreme competitive pressure on the firms in this industry to introduce new products and services so as not to loose their market share and continue to grow. A generally accepted strategy to achieve this challenging task is to be able to introduce a continuous sequence of successful innovations.

Specifically, our study presents the causal structure of the innovation process and the resulting behaviour. For that purpose, system dynamics methodology is employed. System Dynamics is a computer modelling technique to simulate the behaviours of systems with many feedback loops. It is a suitable method for investigating the dynamics of innovation, since it allows for the modelling of interactions and for the observation of resulting dynamic patterns through simulation.

The main performance indicator used in our model is the innovativeness level. As part of this research, the behaviour of the system is analyzed employing parametric analysis.

İNOVASYON DİNAMİĞİNİN
SİSTEM DİNAMİĞİ İLE MODELLENMESİ

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Özet

Bu çalışmanın konusu inovasyon dinamiğinin bir dayanıklı tüketim malları üreticisi firma perspektifinden sistem dinamiği metodolojisi ile irdelenmesidir. Dayanıklı tüketim malları endüstrisi olgun bir endüstri olarak kabul edilmekle birlikte yine de sektördeki firmalar üzerinde pazar paylarını kaybetmeme ve büyüme için yeni ürün ve hizmetler sunma konusunda yoğun bir rekabetçi baskı vardır. Bunu sağlamak için genelde kabul gören bir strateji sürekli başarılı inovasyonlar gerçekleştirebilmektir.

Bu çalışma kapsamında inovasyon stratejileri üzerinde durulmuştur. Bu nedenle sistem dinamiği metodolojisi uygulanmıştır. Sistem Dinamiği modelleme yaklaşımı bir bilgisayar modelleme tekniği olup geribeslemeleri döngülerle gösterebilen bir yaklaşımdır. Bu yaklaşım, etkileşimlerin modellenmesine izin verdiğinden ve dinamik olarak benzetim boyunca davranışları gösterdiğinden inovasyon dinamiklerinin incelenmesi için uygun bir araçtır.

Modelde kullanılan ana performans ölçütü yenilikçilik seviyesidir. Çalışmanın parçası olarak sistem davranışları parametrik analiz kullanılarak incelenmiştir.

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CHAPTER 1

INTRODUCTION

Innovation is a Latin word which means using of new methods in cultural and social environment. Innovation can be defined as a new and different result. Innovation is not only the improvement itself but also it is the economic and social effects due to the differentiation and alteration.

Product development refers to the process by which an organization designs a new product or redesigns and improves an old one. Three functional groups, broadly defined, are involved in this process: design engineering, manufacturing, and marketing. The scope and extent of the process vary widely across and within industries, depending on the complexity of the product involved that's why innovation is a very complex process, which is revealed by numerous factors. In the ever-changing environment, innovativeness is of essential importance. There is a strong competition within the industries and it is important for companies to have a competitive advantage, which can be recognized by the customers. When we talk about innovativeness, it is not only product or service innovativeness but also method and strategy innovativeness. The emergence of an innovative product or service or introduction of a new method in the supply chain can redefine the rules of the game.

The key concept for innovation is change. Managing the change is not a trivial task. Change management includes many parameters such as the existing structure of a company, company culture, resistance to change and many other aspects. Moreover, the success of the company is strongly related to the degree of relevance of the innovation strategy to the general strategy of a company. General strategy of a company should adopt with the innovation strategy, otherwise it needs to be changed in a way that innovativeness is perceived as a necessary tool to maintain the competitive advantage of a company.

In order to analyze the dynamics of the innovation, system dynamics method is chosen. The output of this thesis will be a toll for analyzing the behaviour of the system in the long run.

The organization of this study as follows: Chapter 2 explains the methodology employed. Literature survey on innovation and studies on innovation employing system dynamics are reported in Chapter 3. Chapter 4 explains the proposed model. Chapter 5 deals with the base run, validation and sensitivity analysis of the model. Chapter 6 states the conclusion and some suggestions future study.

CHAPTER 2

METHODOLOGY

Humans live within social systems. Research in natural sciences has come a long way exposing the structure of nature's systems and technology has produced complex phyical sytems but the behaviour of these systems is not widely understood.

A system is defined as the collection of elements that interact over time. The way these elements interact and the relationships among them constitute the structure of the system. The term dynamic means that the elements of the system and their interrelationships change over time. The nature of these changes reflects the behaviour of the system.

System Dynamics is a powerful methodology for developing and analyzing computer simulation models of complex problems. It has its roots in engineering feedback control systems analysis. The methodology was pioneered at MIT in the 1960s and subsequently has been used by major corporations, government ministries, academic institutions, and research centers around the world. System Dynamics models have contributed to corporate strategy formulation and implementation, analysis of technology-based markets, risk management, and evaluation of government regulations.

Definition of system dynamics in the website of System Dynamics Society at (www.systemdynamics.org) is stated as follows "System dynamics is a methodology for studying and managing complex feedback systems, such as one finds in business and other social systems. In fact it has been used to address practically every sort of feedback systems. While the word system has been applied to all sorts of situations, feedback is the differentiating descriptor here. Feedback refers to the situation of X affecting Y in turn affecting X perhaps through a chain of causes and effects. One can not study the link between

X and Y and, independently, the link between Y and X and predict how the system will lead to correct results."

Forrester (1961) states that the System Dynamics philosophy is based on several premises:

1. The behavior (or time history) of an organizational entity is principally caused by its structure. The structure includes not only the physical aspects, but more importantly the policies and procedures, both tangible and intangible, that dominate decision-making in the organizational entity.
2. Managerial decision-making takes place in a framework that belongs to the general class known as information-feedback systems.
3. Our intuitive judgement is unreliable about how these systems will change with time, even when we have good knowledge of the individual parts of the system.
4. Model experimentation is now possible to fill the gap where our judgement and knowledge are weakest by showing the way in which the known separate system parts can interact to produce unexpected and troublesome over-all system results.

Based on these philosophical beliefs, two principal foundations for operationalizing the system dynamics technique were established. These are:

1. The use of information-feedback systems to model and understand system structure.
2. The use of computer simulation to understand system behavior.

The use of information feedback systems:

"Feedback," is the process in which an action taken by a person or thing will eventually affect that person or thing. A feedback loop is a closed sequence of causes and effects, a closed path of action and information. The cause-effect relationships that exist in organizations are dense and often circular. Sometimes these causal circuits cancel the influences of one variable on another, and sometimes they amplify the effects of one variable on another. It is the network of causal relationships that imposes many of the controls in organizations and that stabilizes or disrupts the organization. It is the patterns of these causal links that account for much of what happens in organizations.

The use of computer simulation:

First, managerial systems contain many variables that are known to be relevant and believed to be related to one another in various nonlinear fashions. The behavior of such a system is complex far beyond the capacity of intuition. Computer simulation is one of the most effective means available for supplementing and correcting human intuition (Roberts, 1964). Secondly, the behavior of systems of interconnected feedback loops often confounds common intuition and analysis, even though the dynamic implications of isolated loops may be reasonably obvious. The feedback structures of real problems are often so complex that the behavior they generate over time can usually be traced only by simulation. (Richardson and Pugh, 1981).

A common scientific tool used in investigating problems and solutions is modeling. A model can be defined as “a representation of selected aspects of a real system with respect to some specific problem(s).”(Barlas, 1996). A typical classification of models can be given as descriptive versus prescriptive. Descriptive models describe how variables interact and how the problems are generated. System dynamics models are thus descriptive models. Prescriptive (often optimization) models however assume certain “objective functions” and seek to derive the decisions that optimize the assumed objective functions.

There are many steps in system dynamics modelling. Problem articulation, causal loop diagram of the model, formulations of the model (stock flow diagram), validation and sensitivity analysis. The most important step in modelling is the problem articulation step. In this step, key variables and time horizon are decided. Causal loop diagram and stock flow diagram will be explained in this chapter.

Components of System Dynamics

System dynamics consists of four components: system, feedback, level, and rate. A system is a set of elements sharing a particular purpose within a boundary. Depending on its boundary, a system can be a corporation, an environment, an economic entity, a country, an inventory system, etc. It refers to “reality” or some aspects of reality.

The casual relationship indicates one element affecting another element. In order to model the causality, a causal-loop diagram has been introduced. Causal loop diagram has been used to formulate a cognitive model and to hypothesize the dynamic interactions between elements. Positive and negative polarity is used while representing the feedback of related elements. The dynamic movement of the system can be caused by a feedback loop. There are two types of feedback: reinforcing and balancing. In Figure 2.1, reinforcing feedback loop is stated. The designations “positive” and “negative” indicate whether changes in the feedback system move in the same direction to produce a reinforcing behaviour, or move in opposite directions to produce a balancing, stabilizing behaviour. Causal loop systems are most commonly called feedback systems. In this case, each variable is a cause and effect at the same time.

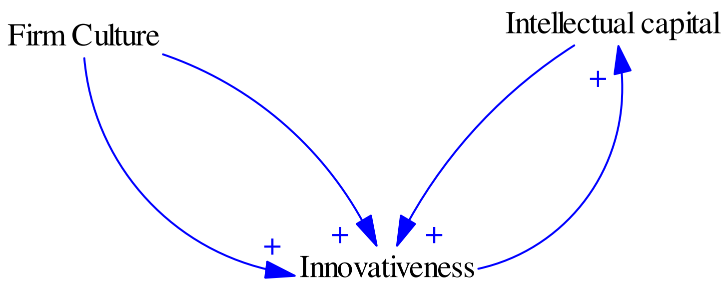

Figure 2.1 The diagram of casual relationship

After a causal loop diagram is built, it is converted to a stock flow diagram. There are two variables required for simulating all elements inside a system: level and rate. The 'level' refers to a given element within a specific time interval. Meanwhile, the rate reflects the extent of behavior of a system. Specifically, the differences between the level and the rate depend on whether the element contains a time factor. The level and the rate can be formulated using the stock-flow diagram (SFD) for a simulation test. The level can be represented with a stock level; the rate is described as a variable on the flow. Stock is represented by a rectangle and flow can be expressed by a double-direction arrow. Converters are variables that are affected by the values of variables linked to them. Clouds represent the sources and sinks for the flows. A source represents the stock. Stocks are the integral of all flows that change them. While stock can be affected by their previous values, converters are affected only by the values of the variables they have a link with. A sample stock- flow diagram is shown in Figure 2.2.

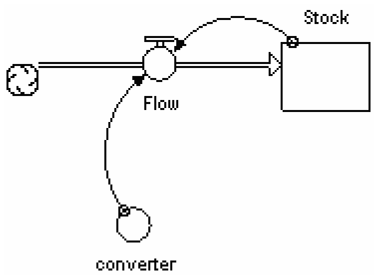

Figure 2.2 Stock-flow diagram

Stocks and flows are the two central concepts of dynamic systems theory. In this step, the formulations are also decided. While modeling soft variables effect formulations are needed. Effect can be shown by using additive formulation or multiplicative formulation. Additive formulation assumes the effects of each input are strongly separable. In multiplicative formulations, variables are affected simultaneously.

Lai and Wahba (2001) state that correctness of the model is relative to its purpose and varies widely. They mention the modeling standards and tips to check for modelers. Naming variables is an important issue for understanding the concept. A good model must show all constants explicitly as individual elements. One must be able to recognize all model elements at a glance. It is not underestimated that stock values can be changed only by flows. No constants should directly enter the stock equation except for the initial values of the stock. Every flow should be connected to a stock. A flow unattached to a stock serves no purpose in the model. Stocks should not be linked to other stocks.

In system dynamics methodology two software packages are mainly used. These are Stella and Vensim. Both are industry standard packages and provide basic aspects of system dynamics modeling. In this research mainly Stella is employed. Vensim is used for drawing causal loop diagrams.

In the next chapter definitions of innovation and innovativeness, innovation types are discussed with a review of innovation literature.

CHAPTER 3

LITERATURE REVIEW

3.1 Innovation and Innovativeness

Competitiveness is a firm's share of its markets for its product. The basic competitive pressure exerted on firms by global competition forces them to look for ways of decreasing their manufacturing costs and improving their innovative technological capability. Companies should develop new organizational and work structures and invest in innovation to confront this challenge (Ulusoy et al., 1999). The companies, which apply successful innovative strategies, demonstrate low risk-averse characteristics and usually remain at the frontier in their own industry. Nevertheless innovation is not a single level activity. Innovation strategy should be accepted and assimilated at every level of a company's organization structure. In all levels, innovation management is a continuous process meaning a lot of observing, learning, training and applying. The amount of time required to gain the returns of the innovative strategy may differ for different industries; however, companies may decrease the waiting time by applying some practices. To begin with, the companies should be able to criticize themselves both in terms of positive and negative progress regarding the innovation strategy. It is important for companies to assess their capabilities with respect to their innovation strategy. Companies can also try to generate new approaches for the innovation management. The performance of the innovation management should be monitored and evaluated. Finally, according to the evaluation results new approaches and applications should be developed. Moreover, companies should encourage creativeness and the employees should be supported to generate new ideas later to be shared within the company.

Being a highly popular concept in today's business world, innovation is heavily investigated in the literature in terms of many aspects: the methods, the reasons, the tools, etc. Acs and Audretsch (1990) investigate innovation from small and big firms' aspect. They compare the concentration of innovation with the characteristics of industries by the scale of firms. Innovation output is analyzed in small and big firms of highly competitive industries. They concluded that small and large scale firms respond differently to the change of market conditions. Utterback (1996) states that adopting the initial product to demand deviations and market opportunities by a systematic methodology of innovation carries companies to the leadership in being the most stable to changes. He also emphasizes the use of technology for competitive advantage and introduces the concept of innovation management. Freeman (1983) defines innovation as the use of new knowledge to offer a new product or service that customers want: it is invention and commercialization.

Prajago (2006) examines the integration of the human and technological aspects of innovation by modelling the innovation stimulus, innovation capacity relationship in determining innovation performance. Feldman and Massard (2002) points at innovation's dependence on knowledge and claims that product innovations combine technologic and scientific knowledge with market knowledge. They also introduce a linear model of innovation in which scientific discovery, product development and market introduction precede each other.

A review of various models for innovation management reveals that management of innovation includes both technological and human aspects. Vrakking (1990) specifically defines the integration of many areas. These are technological resources that are concerned with managing the accumulation of knowledge management of human resources.

Managing the human factors of innovation is based on the premise that it is people and social practices, not technology that leads to innovation. Therefore managers should be directed towards managing people for innovation, and this effort should primarily be directed towards creating an environment that supports innovation. (Kanter, 1985)

Innovation can be a technological change, which may involve product innovation and process innovation, or organizational change, which involve new managerial techniques, or a social innovation. Innovations can be classified as "radical" implying a discontinuous change and introduction of new technologies, or “incremental” implying the gradual improvement of existing technologies and techniques.

Becheikh et al. (2006) present a systematic review of empirical articles about technological innovations published between years 1993 and 2003. The scope of the study is to identify how innovations occur in firms and where the conclusions about innovativeness converge.

Innovation may take place at different stages of a supply chain such as manufacturing, product and process design, marketing and logistic services. At each stage, innovations have social, economic and technological impacts. Depending on the characteristic of the company and at which stage the innovation is taking place, innovations can be grouped as product or service innovations, process innovations, organizational innovations, marketing related innovations, social innovations, environmental innovations and system innovations (Elçi,2006):

1. Product Innovation: Development of a new product or improvement of an existing product is called product innovation. 3M is famous for its exemplary product innovations. Sticking plasters and digital recognition technology are the examples of 3M’s product innovations. Emphasis on these simple but important needs gave the company a competitive edge over its competitors. Sony is another company which is also famous for its innovations. Compact disk, walkman, minidisk, DVD player and play station are Sony’s product innovations. Another example for product innovation is Colin’s Jeans’ product that can be worn by two sides. DYO’s clever dyes, developed by using nanotechnology, are also examples of product innovation.

2. Process Innovation: It is a way of development of a different production or distribution method. The basic example for process innovation is the just-in-time production. Computer aided design developed by Goldaş in 1993 is a good example for process innovation. .

3. Service Innovation: Innovation is different in service systems compared to manufacturing systems. Service innovations require the firms to develop new human resources related approaches and improve technological and organizational abilities. For example, Axa Oyak is the first company to serve online services in its sector. Also, “yemeksepeti.com” is the first online food order website, which is a successful example for service innovation.

4. Organizational Innovation: It involves the introduction of new or improved working methods, business models and practices. Kaizen is an example for organizational innovation focusing on the improvement of existing processes within an organization. In Kaizen, all employees are required to create a continuous enhancement in their processes all the time. Moreover, Dell introduced the “make to order” method in the hi-tech industry and this method increased Dell’s income from 2 billion USD to 16 billions USD in 1998.

5. Marketing Innovation: It consists of introduction of new marketing strategies such as new pricing strategies, promotion approaches and product differentiation through improved packaging techniques.

6. Social Innovation: Social innovation involves enhancement of social needs of a community. Combining health institutions under one umbrella organization is a recent social innovation accomplished by the Ministry of Health of Turkey. Social innovations should be thought as a whole with other related innovations. Extending high school education from three years to four years was another social innovation in Turkey.

7. Environmental Innovation: Environmental innovation can be defined as the introduction of new mechanisms, approaches or products that will reduce the use of natural resources and protect the natural environment and improve the environment quality. System re-designs, optimization of existing products, and functional innovations lead to environmental innovations.

8. System Innovations: Pollution and greenhouse gas emissions are only two of the structural problems that modern societies face. Structural innovations include a series of changes including technology, methods and policies, approaches, markets and infrastructure.

In the Oslo Manual (2005), it is seen that four different innovation types are introduced. These are product innovation, process innovation, marketing innovation and organizational innovation.

1. A product innovation is the introduction of a good or service that is new or significantly improved. Product innovation includes in significant improvements in technical specifications, components and materials or other functional characteristics.

2. A process innovation is the implementation of a new or significantly improved production or delivery method. Objectives of the process innovation are decreasing unit costs of production and increasing quality.

3. A marketing innovation is the implementation of a new marketing method involving significant changes in product design or packaging, product placement, product promotion or pricing.

4. Organizational innovation is the implementation of a new organizational method in the firm's business practices, workplace organization or external relations.

Innovativeness is one of the basic elements of firms' business strategies to enter new markets by providing competitive advantage to the company**.** Many researches claim that firms can overcome their competitive problems only through innovations (Evangelista et al. 1998). Hence, the modern companies need to be innovative in order to compete better in their market.

Innovativeness is a process that involves generation, adoption, implementation and incorporation of new ideas and practices within an organization (Wan et al. 2005). It is seen that frequent internal communication, greater decentralization of decision-making authority are positively related to firm innovative capability**.**

Salavou (2004) states that the difference between innovativeness and innovation should not be underestimated. Innovation tries to integrate the adoption or/and implementation of "new" defined rather in subjective ways. On the other hand innovativeness appears to embody some kind of measurement contingent on an organization's proclivity towards innovation. Innovativeness is critical as members of companies diversify; adapt their firms to contest evolving market and technical conditions (Akova et al. 1998).

Innovativeness is separated into two different categories. Behavioral innovativeness is defined as a characteristic of a firm's intellectual capital, which is formed by sum of innovative capabilities of firm's employees and management. Basic property of innovativeness is internal openness to new ideas which can be seen as a crucial factor that affects innovative outcomes. On the other hand, strategic innovativeness evaluates an organization's capability in order to reach specific organizational objectives (Wang and Ahmed, 2004).

As it is explained earlier, innovation is the key element for being successful in the long run. The companies should be aware of the innovation determinants. The innovation determinants can be classified into two groups. These are in-firm (indigenous) parameters and out-firm (exogenous) parameters. The indigenous parameters include general firm characteristics, firm structure and firm strategies. Exogenous parameters are sectoral conditions and relations. In this study, firm structure is modeled dynamically. Firm structure includes firm culture, intellectual capital, and managerial characteristics.

3.2 System Dynamics and Innovation

In today's highly changing environment companies need to be more innovative. Free thinking is needed in many parts of the companies. Also free thinking should be effective and should have the ability to change the old and ineffective practices. Being innovative and making innovations become more important as the competition intensities. Managing innovation properly is not an easy task. Many academicians try to model innovation by using system dynamics methodology to gain insight for the complex system resulting.

Galanakis (2006) reports on a system dynamics model of new product design and development process. In this model, there is a variable, which is called "new ideas generation" (Figure 3.1). In this thesis, this variable is called as innovativeness with the same meaning.

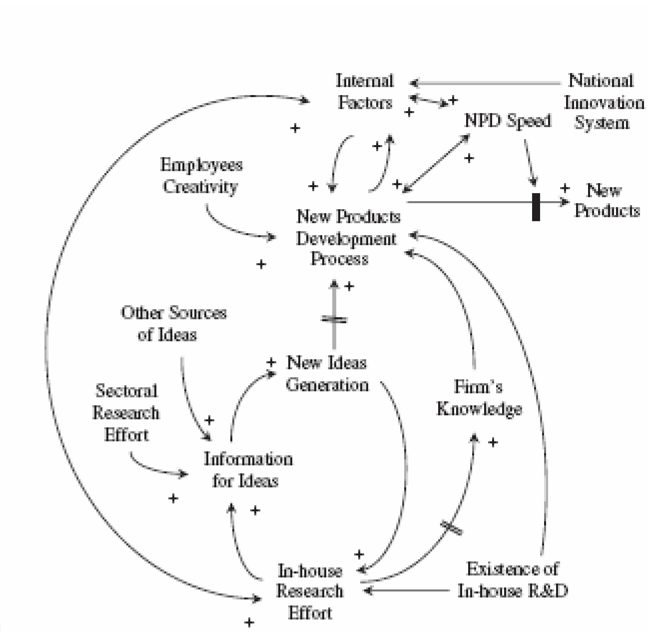

Figure 3.1: New product development causal loop diagram (Galanakis, 2006)

Tunzelman (2005) describes the dynamic processes of the Taiwanese IC industry system of innovation and tries to explain the interdependence and interaction among capital flows, human resource flows, knowledge and technology flows, and product flows. (Figure 3.2)

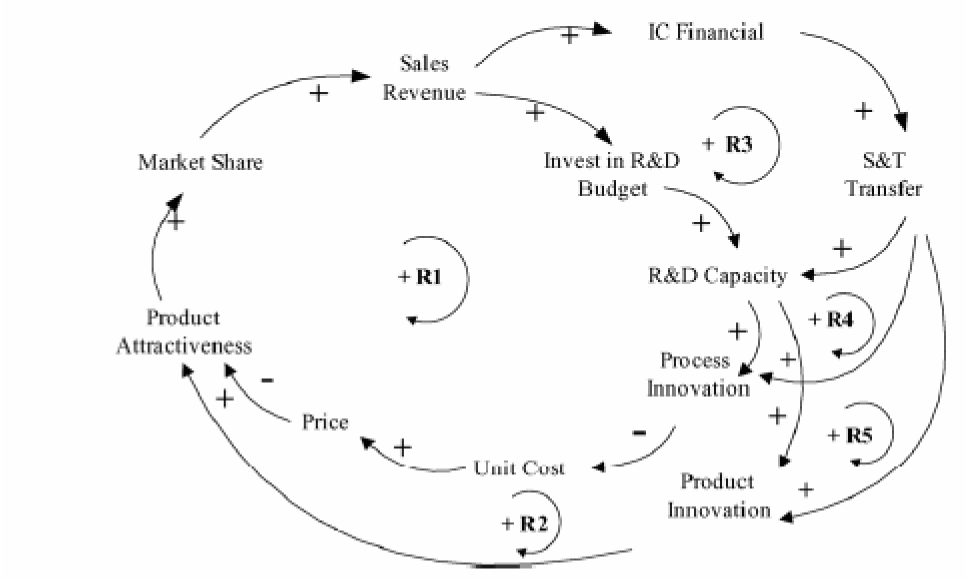

Figure 3.2: Financial, innovation and product causal loop diagram (Tunzelman, 2005)

Woodside (2004) includes a proposal for advancing from one-directional structural equation modeling of innovativeness and business performance to system dynamics modeling that includes real-world feedback loops (Figure 3.3).

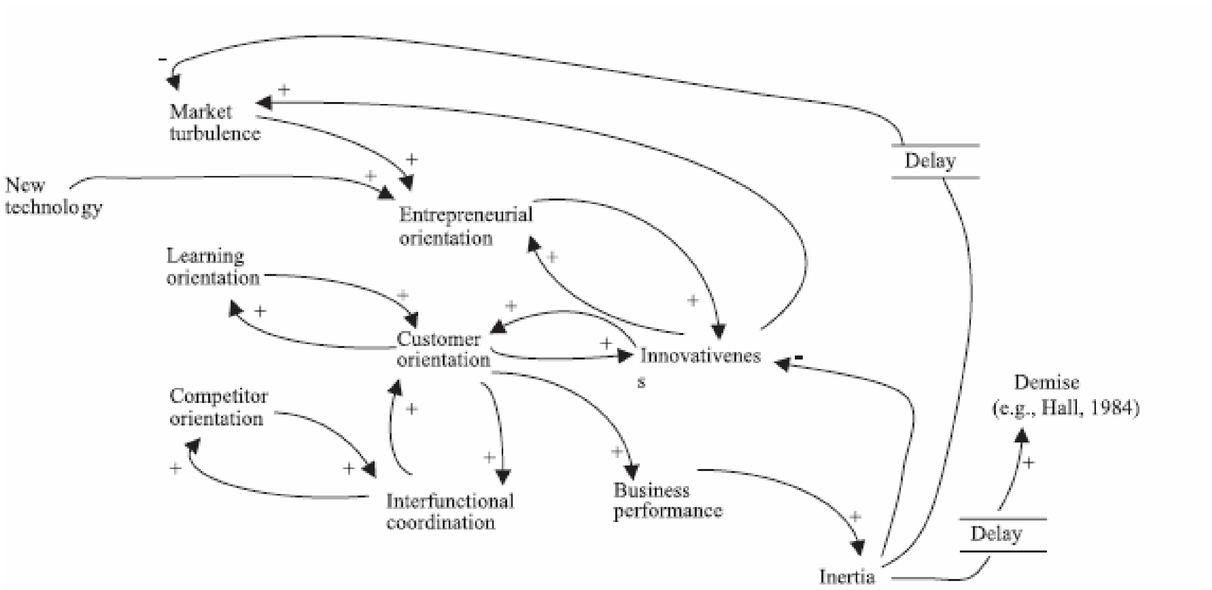

Figure 3.3 Innovativeness causal loop diagram (Woodside, 2004)

Sterman (1998) describes a multiple-phase project model, which explicitly models processes, resources, scope, and targets (Figure 3.4). The model explicitly portrays iteration, four distinct development activities and available work constraints to describe development processes. The model is calibrated to a semiconductor chip development project. Impacts of the dynamics of development process structures on research and practice are discussed.

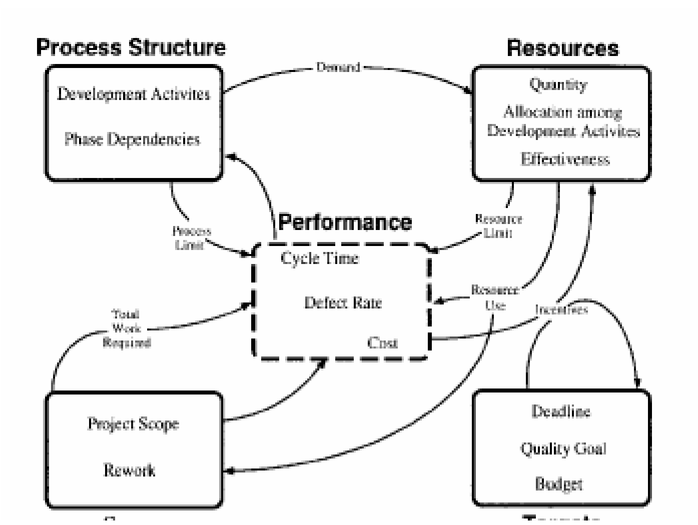

Figure 3.4 Dynamics of development process (Sterman, 1998)

Milling (2002) analyzes strategies for new products, especially price strategies, and includes the processes of research and development (R&D) in a comprehensive model, which is then disaggregated to explicitly take into consideration the actions of different competitors (Figure 3.5)

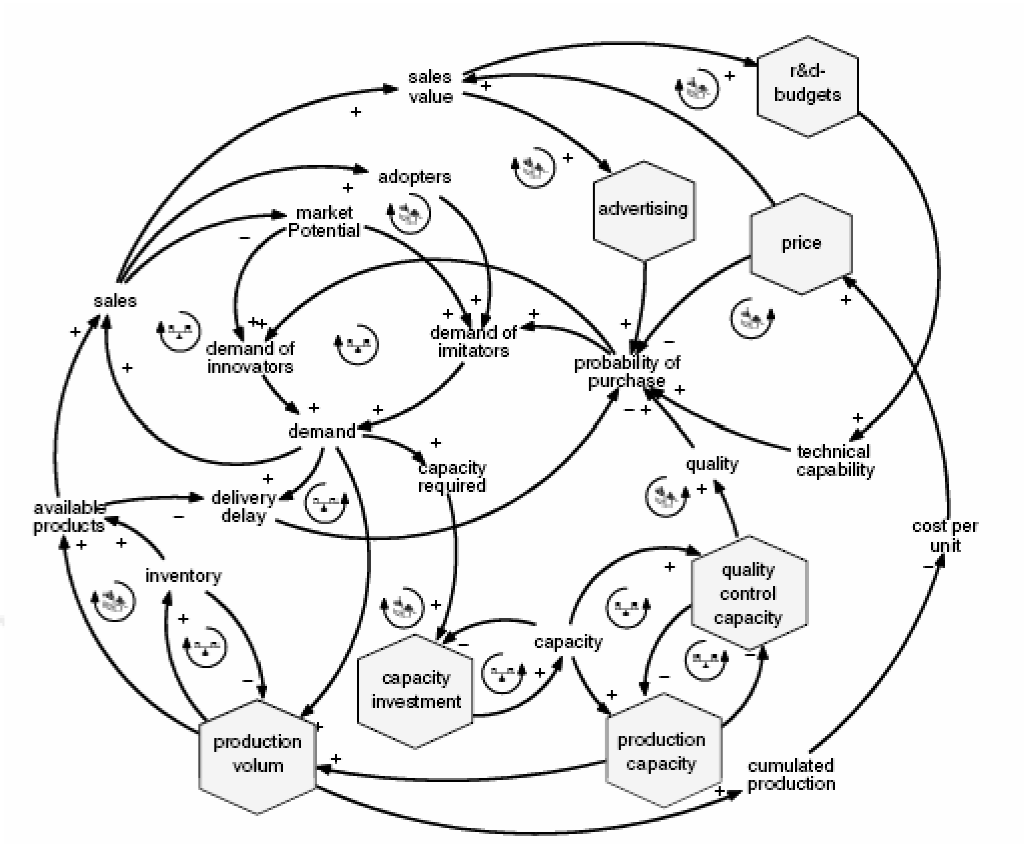

Figure 3.5 New product causal loop diagram (Milling, 2002)

As it seen, innovation can be modeled from different perspectives by using system dynamics methodology. Soft variables can also be added to the model and can be quantified by using scales. In the next chapter, the model proposed is presented using causal loop diagrams.

CHAPTER 4

PROPOSED MODEL

This study aims to see the dynamic pattern of innovativeness according to the related variables. The model is divided into 2 main parts. These are as follows: (1) Firm culture (2) Intellectual capital.

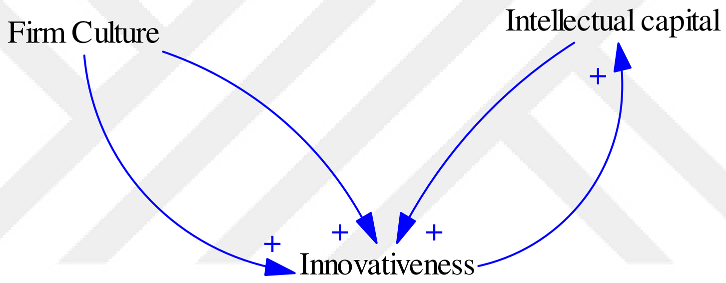

Figure 4.1: Base causal loop diagram

The base causal loop diagram of the model is displayed in Figure 4.1. In the academic literature, numerous authors studied firm structure and intellectual capital and tried to find out appropriate model for innovativeness. Differently, this study represents the relationships in a dynamic environment and analyzes the behaviour of the system. The next sections deal with explanations and relations of model variables.

4.1 Firm Culture

Organizational culture is the bundle of values, norms, and rituals that are shared by people in an organization and govern the way they interact with each other and with other stakeholders. An organization's culture can have a powerful influence on how people in an organization think and act. Organizational values are beliefs and ideas about what goals should be pursued and what behavior standards should be used to achieve these goals. Values include entrepreneurship, creativity, honesty, and openness.

Organizational norms are guidelines and expectations that impose appropriate kinds of behavior for members of the organization. Norms (informal rules) include how employees treat each other, flexibility of work hours, dress codes, and use of various means of communication such as e-mail. Organizational rituals are rites, ceremonies, and observances that serve to bind together members of the organization. Examples of rites are weekly gatherings, picnics, awards dinners, and promotion recognition.

In innovative firms, the values and beliefs favor collaboration, creativity, and risk-taking (Jassawalla and Sashittal 2002). These firms make these rituals to reinforce these values and beliefs.

Amar (2004) states that one of the sources of motivation is the organizational system, which includes the management system and the organizational culture. According to Amar, an outcome of the job is another motivator. The outcomes include all kinds of known and unknown extrinsic and intrinsic rewards and punishments. Salary can be thought as an outcome of the job.

In our model, firm culture is shaped by internal sub-factors. These sub-factors of firm culture are support of top managers, communication ability inside the firm, goodness of the reward system (Souder, 1981). These factors can be seen in Figure 4.2. Centralization affects firm culture indirectly. The employees, who feel the top management support, have a higher motivation in order to be more creative and innovative (Tatikonda and Rosenthal, 2000).

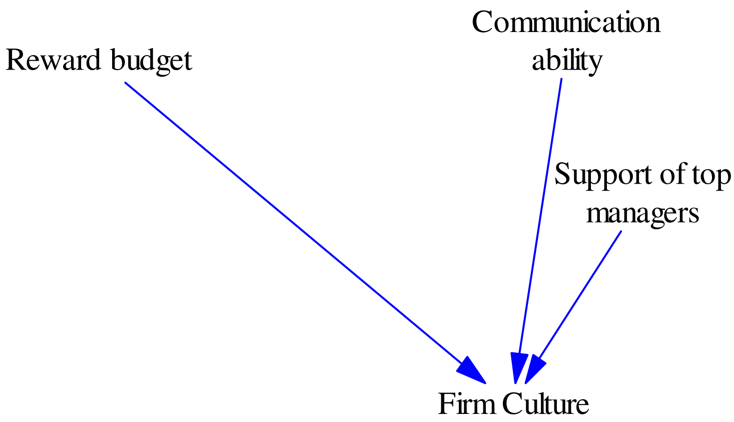

Figure 4.2: Firm culture elements

Various authors stressed that management support towards employees is a critical factor to conduce an innovative environment. When managers give value to the employees, the employees become more innovative and feel themselves as part of the company (Slevin and Covin, 1990; Honig, 2001; Hornsby et al., 2002). Nepal and Dulaimi (2004) hint that managers' behaviour can encourage employees for developing new ideas. According to Nepal and Dulaimi, there are two critical elements that lead to innovations. These are motivation created by organizational climate and managers' behaviour.

Rewards are also very important motivating factor for the employees to be successful in their jobs. The reward system motivates them to reach business targets (Lawler and Porter, 1967). The managers need to provide necessary resources to employees in the innovation process, if they request from their employees to be innovative (Sykes and Block, 1989). It is also clear that innovativeness will increase the support of top managers to employees. Moreover, since employees like to be rewarded in their work, management has to respond to it by providing some incentive to motivate and to satisfy them in their innovative activities (Antoncic and Hisrich, 2001).

Moenaert et al. (1994) investigated the effects of project formalization, centralization and flexibility for innovation success. They stated that communication flows between R&D and marketing departments develop with these factors.

Studies by Jaworski and Kohli (1993) and Menon et al. (1999) show that innovative culture is a fundamental antecedent of effective marketing strategies of the companies. They report that the components of firm structure such as communication quality, formalization and centralization have different effects on the outcomes measured and market performance.

4.2 Intellectual Capital

Intellectual capital (IC) is investigated under three subgroups: human, structural and relational capital. Human capital is the collection of intangible resources that are embedded in the members of the organization. It consists of skills, know how, and motivation. Structural capital is the knowledge embedded within the systems, routines and procedures of an organization. Relational capital involves customer preferences, market channels including suppliers (Narvekar and Jain, 2006).

Huang (2007) also proposes a grouping of IC items based on empirical evidence taken from the managers' responses to questions about IC inside their companies. The results show that intellectual capital consists of three subgroups and these are human capital, structural capital and customer capital.

The Organization for Economic Co-operation and Development (OECD) describes IC as the economic value of two categories of intangible assets of a company. These are organizational (structural) capital and human capital. In this study, this classification is used.

IC is defined as any factor that contributes to the value generating processes of the company, is under the control of the company and is created by the company (Bontis, 1998). It is seen that a strategy that leverages the organization's intellectual capital provides the organization a competitive advantage and thus improves performance. Basic premise of the study is that IC influences innovation and innovation influences firm performance.

IC has received much attention but there is little agreement about the definition of IC. As IC is a multi-disciplinary concept, the understanding of it varies depending on the different disciplines. Chen (2003) describes IC as knowledge, capabilities, and relationships at organizational level. Human capital is described as the talent level of the employees, skills and capabilities. Structural capital (organizational capital) is defined as organizational capabilities, patents, and copyrights. Relational (social) capital is defined as relationships with suppliers and strategic partners. Social capital consists of the accumulation of active connections among people in a network (Cohen and Levinthal 1989). The relational dimension of social capital concerns the nature of the connections between individuals in an organization. The cognitive dimension concerns the extent to which employees within a social network share a common perspective or understanding (Bolino, 2002). Social capital is valuable because it facilitates coordination, reduces transaction costs, and enables the flow of information between and among individuals. In other words, it improves the coordinated effort and organization. Better knowledge sharing can lead to increased trust and better decisions. Teamwork can lead to inventiveness, creative collaboration, and a good spirit.

Cohen and Levinthal (1989) state that human capital of a firm plays a vital role in innovativeness. The core competencies of a firm are its unique skills and capabilities. A capability is the capacity of the firm, or a team within the firm, to perform some task or activity. We call this as talent level in our model. In Figure 4.3 elements of human capital can be seen. Firms with core competencies that match those necessary to effectively implement their business model have the best chance to succeed. It is very important that the core competencies of the firm match the requirements of the business.

All firms know that attracting and retaining the best people is the key to their future success. However, open competition for other companies' employees is now an accepted fact. Leaders know that in entrepreneurial markets, fast-moving firms are competing for the best people. New ventures pursuing important opportunities can attract talented people. By a person's talent, we mean that person's recurring patterns of thought, feeling, or behavior that can be productively applied and play a significant role in performance (Buckingham, 2005).

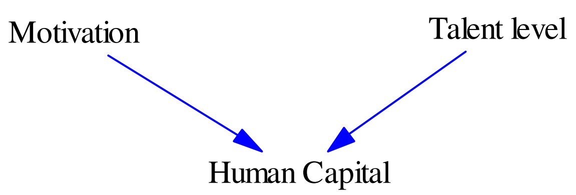

Figure 4.3: Human capital elements

Knowledge assets and intellectual capital are potential sources of wealth. The creation and management of knowledge can lead to new, novel applications and products. Sharing knowledge throughout a firm can enhance the firm's processes and core competencies, thus making the firm more innovative and competitive. Most technology ventures are based on knowledge and intellectual property that must be enhanced and managed. Knowledge is stored in documents, databases, and people's knowledge accumulation. Knowledge is shared by people and is embedded within the business processes of the firm. Social capital contains the relationships among the members of organizations, the collaboration with suppliers, ability to learn together or to teach to each other, and the ability of finding, analyzing and solving common problems (Walker et al., 1987). We do not model social capital in this thesis.

From the generation of new ideas through the launch of a new product, the creation and exploitation of knowledge is a core theme of the new product development process. In fact, the entire new product development process can be viewed as a process of embodying new knowledge in a product. (Rothaermel, 2004). The knowledge of a firm encompasses (1) cognitive knowledge, (2) skills, (3) system understanding, (4) creativity, and (5) intuition. The first three forms of knowledge can be codified and stored. The last two forms of knowledge are types of trained intellect that people possess but are difficult to codify.

Information that does not enable an action of some kind is not knowledge. Knowledge comes from the ability to act on information as it is presented. It truly is power, giving an organization the ability to continuously improve itself. The power of knowledge depends on the company's ability to provide a supportive environment: a culture that rewards the sharing of knowledge across various barriers. The company that develops the right set of incentives for its employees to work collaboratively and share their knowledge will be successful in its knowledge management effort. Knowledge management has several benefits: it fosters innovation by encouraging a free flow of ideas, enhances employee retention rates, enables companies to have tangible competitive advantages, and helps cut costs. Knowledge can be seen as a source of innovation and change leading to action. Also, it provides a firm with the potential for novel action and the creation of new ventures. With increased flow of new information, firms need to develop the means to convert that information into insight (Ferguson et al., 2005). Knowledge creates real wealth for a new venture through multiple applications which can have breadth across an organization. Thus, the firm's IC is the combination of its human capital, organizational capital and relationship capital.

In our model organizational capital consists of intellectual property (IP) and infrastructure. It can be seen in Figure 4.4. Subramaniam and Youndth (2005) examined the importance of intellectual capital of a company. They stated that organizational capital positively affects incremental innovative capability.

Continuous technological change is often cited as a prerequisite for competitiveness and survivability of companies and whole economies. Although technology influences all activities in a company's value chain, technology may affect in particular a company's competitiveness in the field of manufacturing. Products manufactured and sold to the customer, processes used to make the products, and information systems used to integrate the various areas of a company are each a part of the technology in use and are expected to show an impact on several performance measures of the manufacturing system. Hence, effective implementation and use of technology is commonly seen as a strategic weapon in the battles of a company against competition (Porter, 1985). Kameoka (1996) defines technology as the combination of IP and infrastructure. As the budget for infrastructure increases the company will increase the amount of infrastructure so that work will be done in an efficient way.

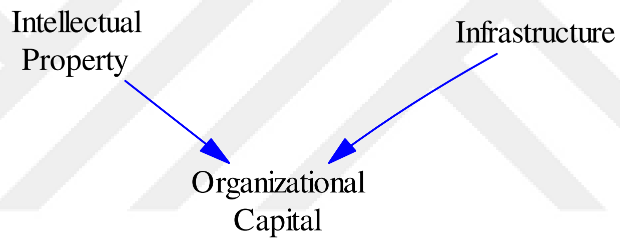

Figure 4.4: Organizational capital elements

Intellectual asset, which is a subset of ideas, is called as intellectual property, that can be legally protected (Davis, 2001). Property is defined as something valuable that is owned, such as land or jewelry. Furthermore, we should distinguish real property (or physical property) from IP. IP is valuable intangible property owned by persons or companies. IP includes trade secrets, trademarks, copyrights, patents, and other forms. Since knowledge and innovation are keys to competitive success, the management of IP is important to most firms. For many firms, intellectual assets are the wellsprings of wealth and competitive advantage.

IP can be obtained by purchasing or by the firm R&D itself. Tunzelman (2005) states that if the R&D budget increases, more will be invested in raising R&D capacity. Hence, this will increase the innovation rate. Maier (1998) also pointed out that the increase in R&D budget will also increase technical capability in his influence diagram. In our model, we also divide IP resources into two parts as mentioned above.

A trade secret is a confidential intellectual asset that is maintained as a secret by the owner. A trade secret is limited to knowledge or methods that are not publicly known, derived, or reverse-engineered. The period of life for a trade secret is potentially indefinite. When IP is difficult to defend, it may be useful to develop a strategy to deter misappropriations. (Anand and Galetovic, 2004). Another strategy is to make the firm's IP require a complementary product that the firm controls. A patent grants inventors the right to exclude others from making, using, or selling their invention for a limited period of time. Utility patents are issued for the protection of new, useful, non obvious, and adequately specified processes, machines, and manufacturing processes.

Patents are granted to new and useful machines, manufactured products, and industrial processes, and to significant improvements of existing ones. Patents are also granted to new chemical compounds, foods, and medicinal products, as well as to the processes for producing them. Design patents are issued for new original, ornamental, and non obvious designs for articles of manufacture. For example, the new design of a computer case could be submitted for a patent. Plant patents are issued for certain new varieties of plants that have been asexually reproduced.

A business method patent is actually a type of a utility patent and involves the creation and ownership of a process or method. The patent registration process requires an application that includes a clear, concise description of the invention and a statement of ownership. It also defines the boundaries of the exclusive rights that the inventor claims. Furthermore, a trademark is any distinctive word, name, symbol, slogan, shape, sound, or logo that identifies the source of a product or service. A registered trademark is renewable indefinitely as long as commercial use is proven. A new venture should consider trade marking its company name, symbol, or logo. A copyright is a right of an author to prevent others from printing, copying, or publishing any of his or her original works.

Licensing is a contractual method of exploiting IP by transferring rights to other firms without a transfer of ownership. A license is a grant to another firm to make use of the rights of the IP. This license is defined in a contract and usually requires the licensee to pay a royalty or fee to the licensor. As a result, IC is the organization's most important asset. It is more valuable than the firm’s other physical and financial assets. Many firms depend on their patents, copyrights, software, and the capabilities and relationships of their people. IC determines success or failure.

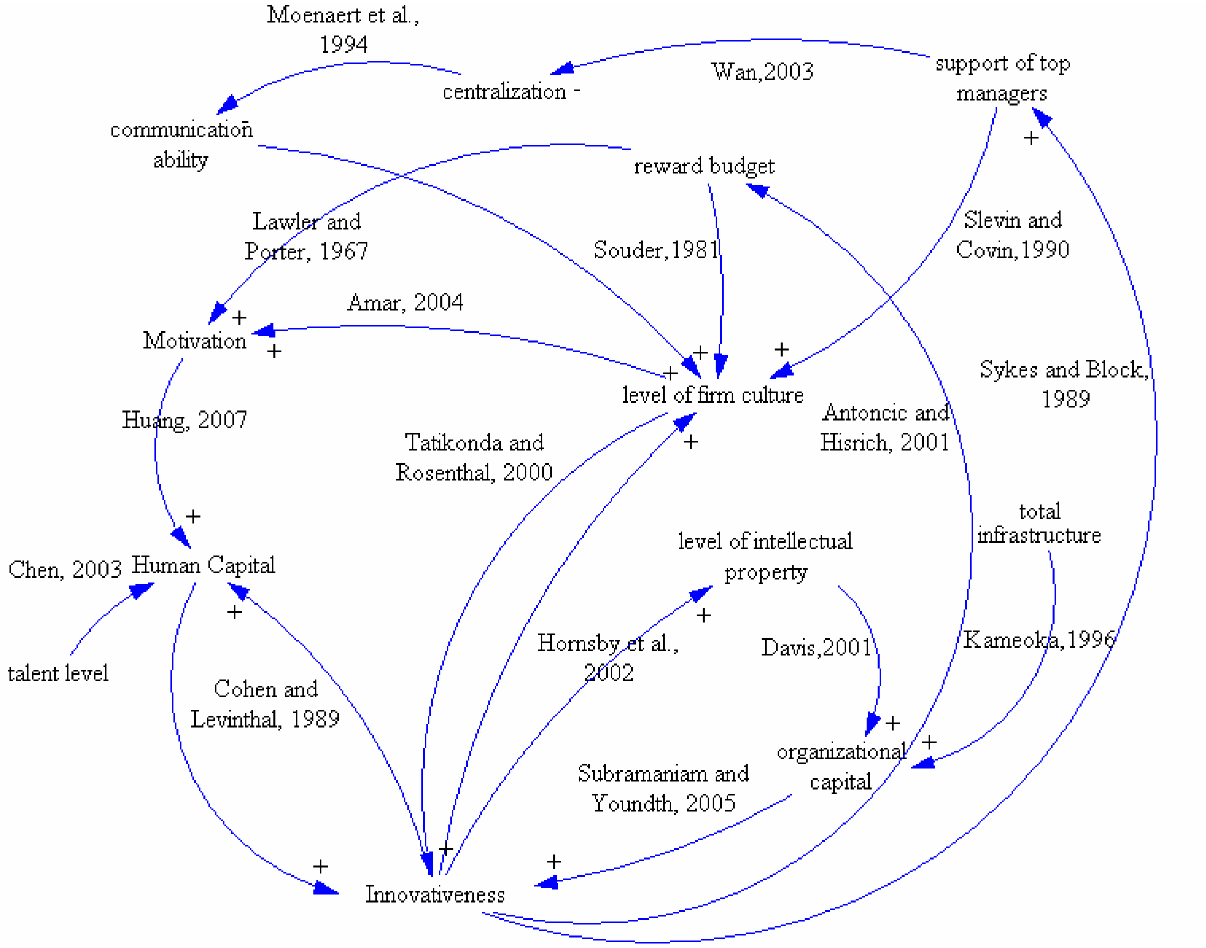

Figure 4.5 Causal loop diagram of the proposed model

The overall causal loop diagram of the model is given in Figure 4.5. Firm culture and IC are the main structures of the model. As the level of the firm culture increases, innovativeness increases. Also as the level of intellectual capital increases, innovativeness increases. The relations of the causal loop diagram are based on a literature review. The relationships are mentioned with their references in the figure.

CHAPTER 5

RESULTS AND SENSITIVITY ANALYSIS

5.1 Results

In the model, we assume the initial values of the stocks as 1 and also we take the reference level of stocks as 1, which means we are at the same level with the competitor.

Table 5.1: Initial values of the stocks

	Initial Values of Stock	Reference Level of Stocks
Level of Firm Culture	1	1
Human Capital	1	1
Motivation	1	1
Intellectual Property	1	1
Infrastructure	1	1
Organizational Capital	1	1
Innovativeness	1	1

In this model, time horizon is taken as 48 quarters which means 12 years. Since we are trying to measure innovativeness in the firm, the effect of innovativeness shows its effect in a longer time. Firm culture, IP, organizational capital and human capital conduce an environment which is innovative.

In the project funded by TÜBİTAK and titled "Innovation Models and Implementations at Firm Level in Manufacturing Industry", 1 to 5 scale was used. (TÜBİTAK, 2007). That's why we take the variables values between 1 to 5 in order to plot the graphical functions and the effect of these variables change between 0-1. In the Tubitak project it is seen that the effect of firm culture, human capital, organizational capital can increase limitedly and after a certain time they converge. That's why we take the effects as S shaped functions. Functions are mentioned in the Appendix B.

Decrease fractions are assumed as 0.01 for the base run
Base Run Results

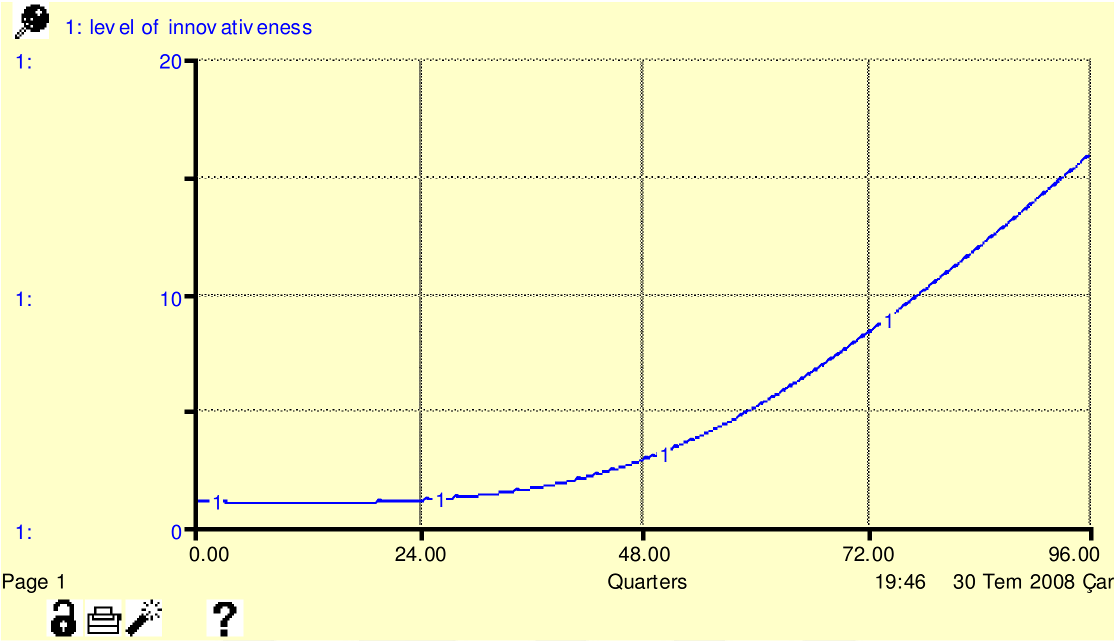

Figure 5.1 Base run of the level of innovativeness

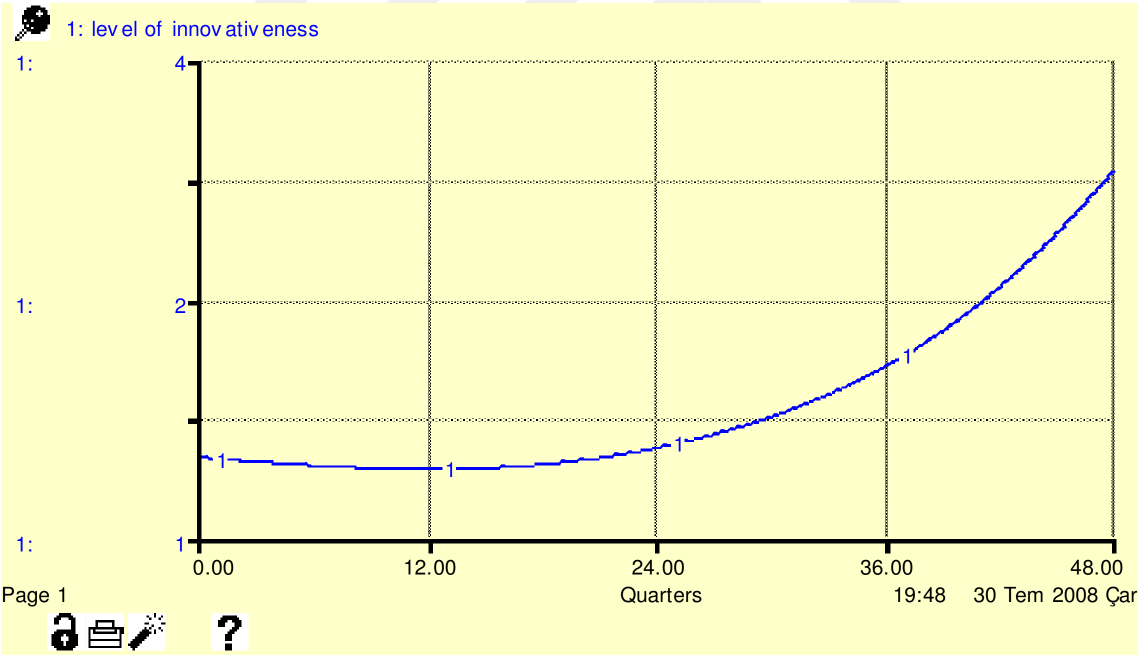

Figure 5.2 Base run of the level of innovativeness

We see that at first innovativeness does not increase deeply, but after 6 years the increase in the innovativeness shows itself better. We also know from the literature that innovativeness can not be seen quickly.

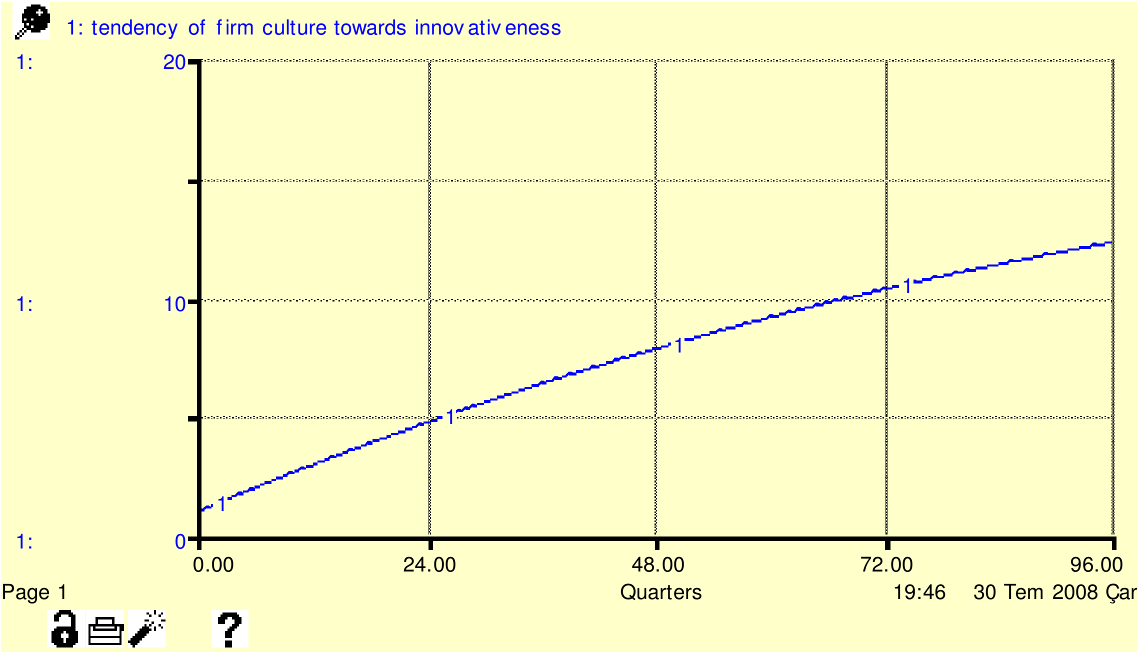

Figure 5.3 Base run of firm culture

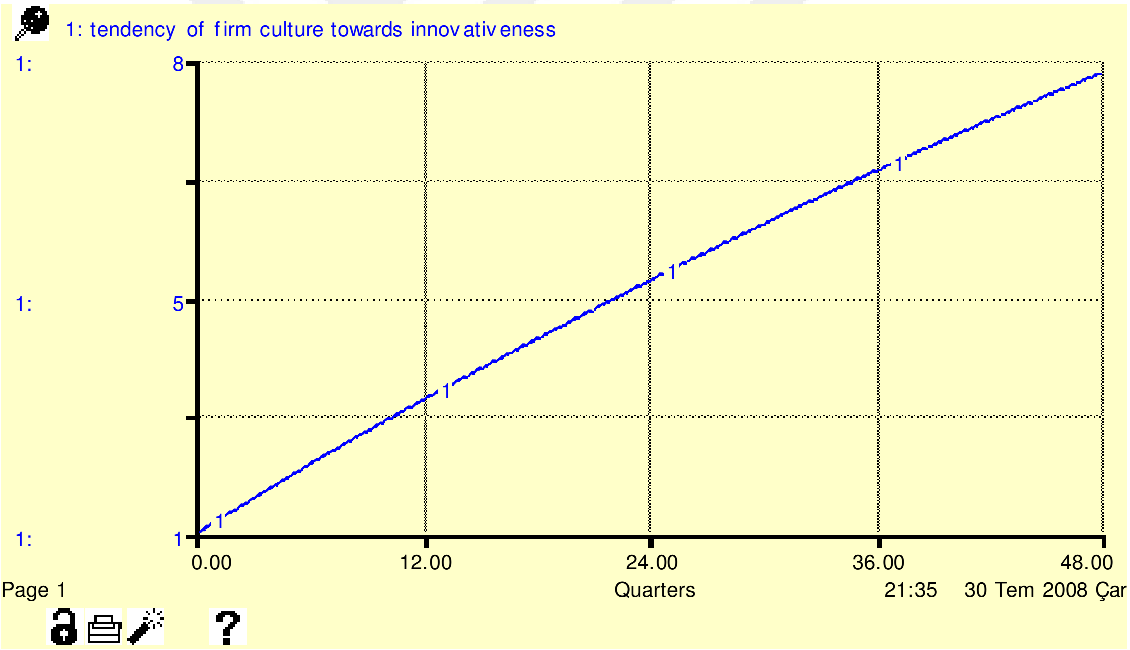

Figure 5.4 Base run of firm culture

We model the factors which affect innovativeness positively. That is why it is normal to see increasing functions. We see that firm culture increases 8 times bigger to the initial value in the 48 quarters. There is a fundamental increase in the level of firm culture which is desired.

Table 5.2 Base run values of the stocks

Base Run

15:52 07/08/2008 Table 2 (Base Run)

Quarters	level of innovativeness	tendency of firm culture	level of human capital
.0	1.00	1.00	1.00
4.0	0.96	1.69	1.04
8.0	0.94	2.35	1.07
12.0	0.93	2.98	1.11
16.0	0.94	3.58	1.15
20.0	0.98	4.17	1.19
24.0	1.06	4.75	1.24
28.0	1.18	5.31	1.31
32.0	1.34	5.85	1.40
36.0	1.57	6.38	1.53
40.0	1.87	6.88	1.71
44.0	2.28	7.37	1.96
Final	2.80	7.84	2.23

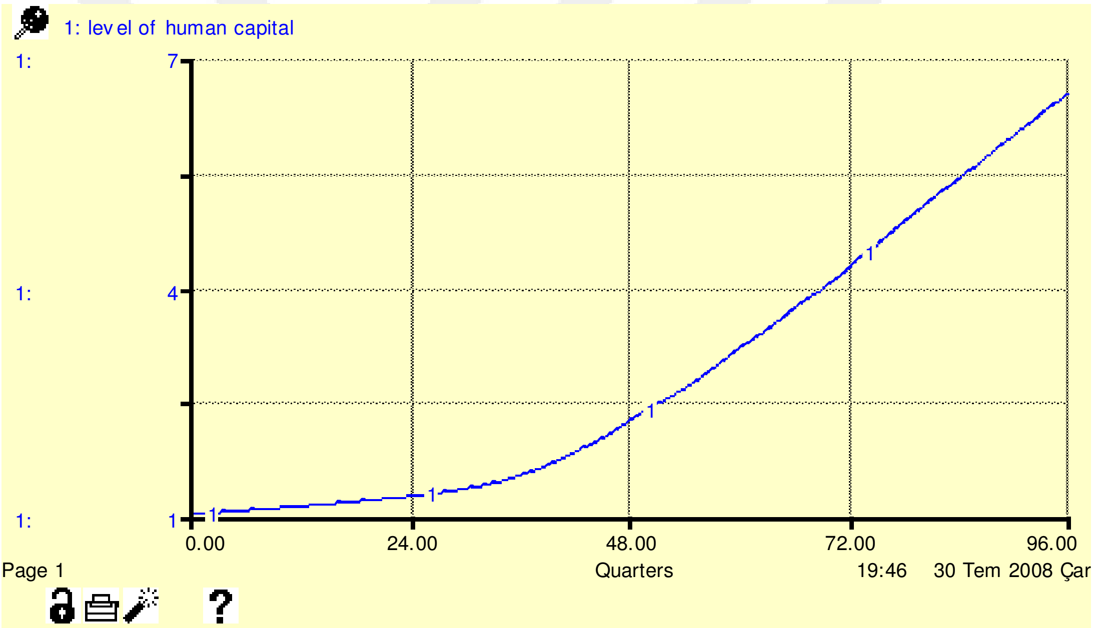

Figure 5.5 Base run of human capital

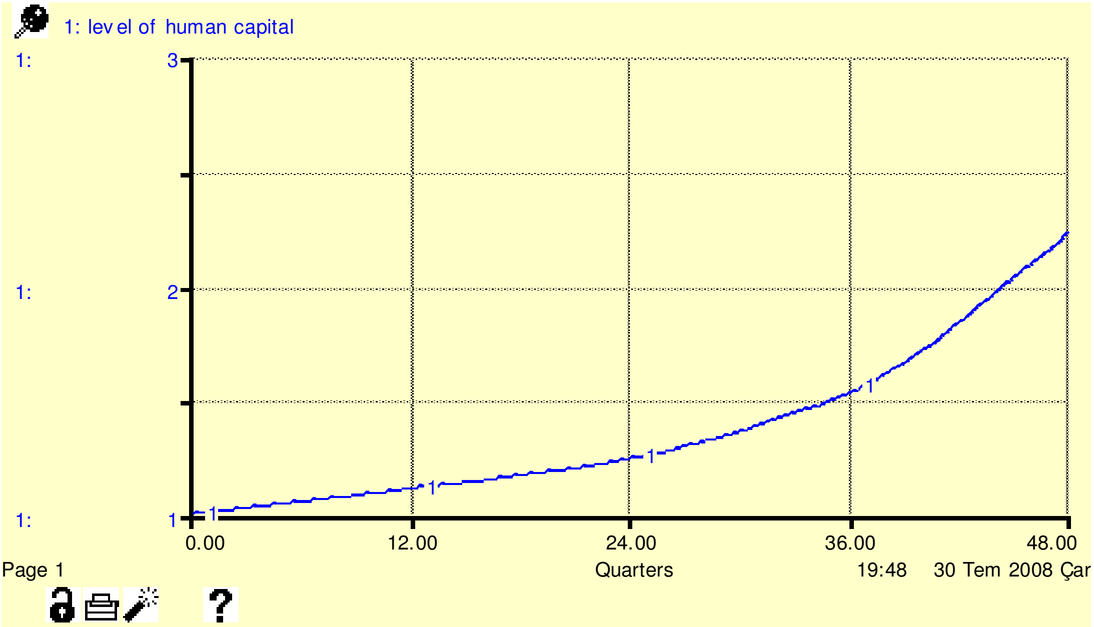

Figure 5.6 Base run of human capital

It can be seen that the increase is slow until sixth year. After then increase in level of human capital becomes significant.

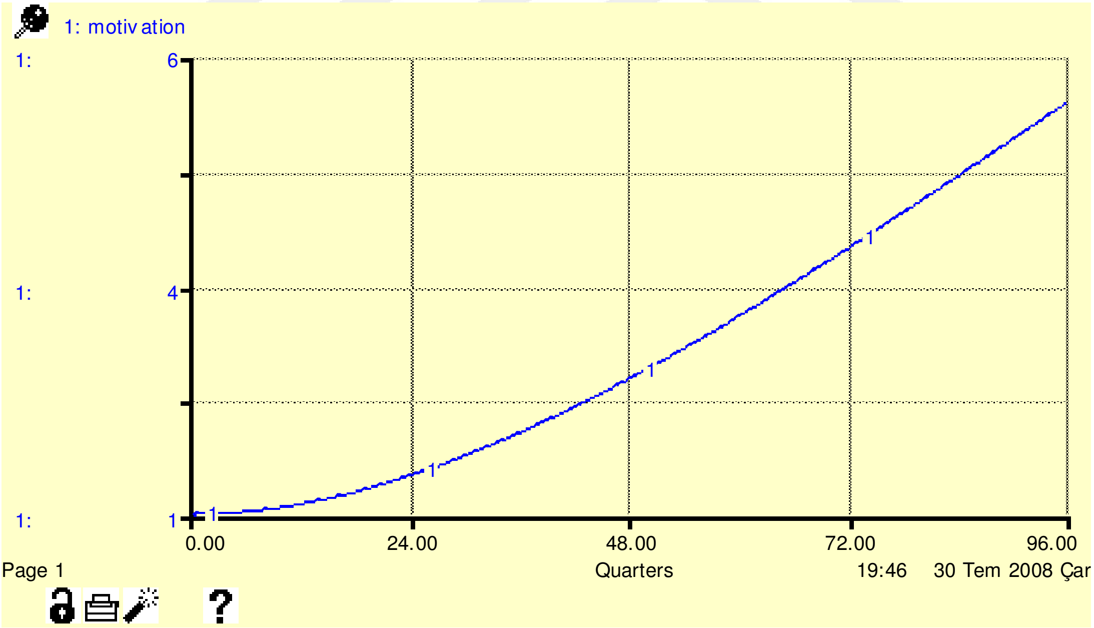

Figure 5.7 Base run of motivation

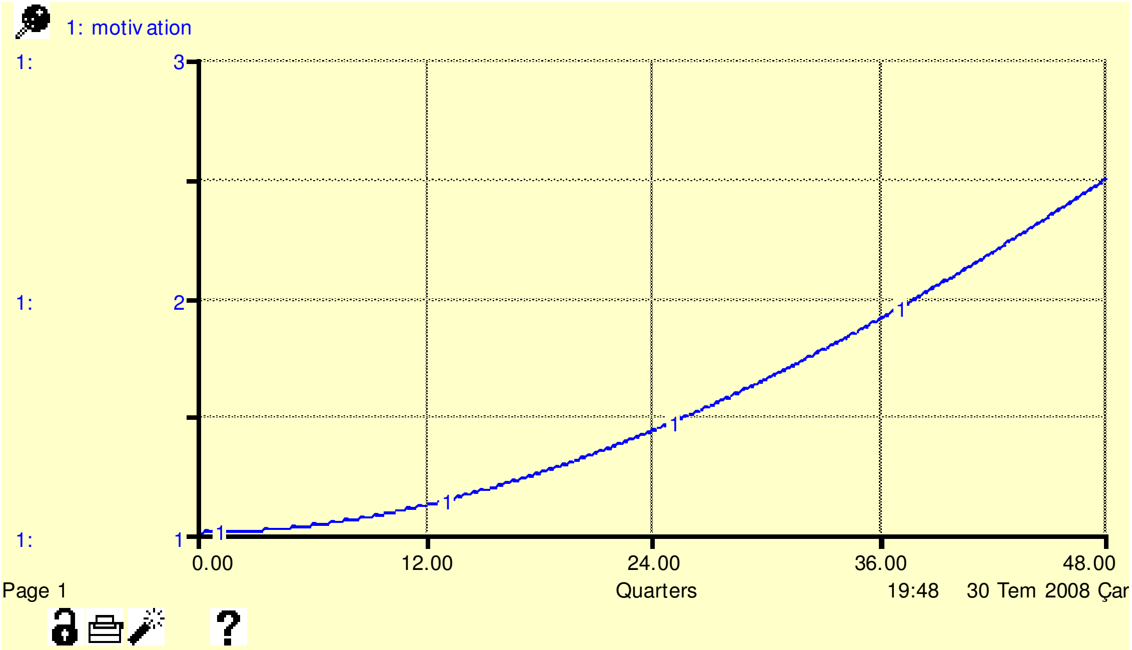

Figure 5.8 Base run of motivation

After 48 quarters motivation reaches 2.5 times bigger than the initial value.

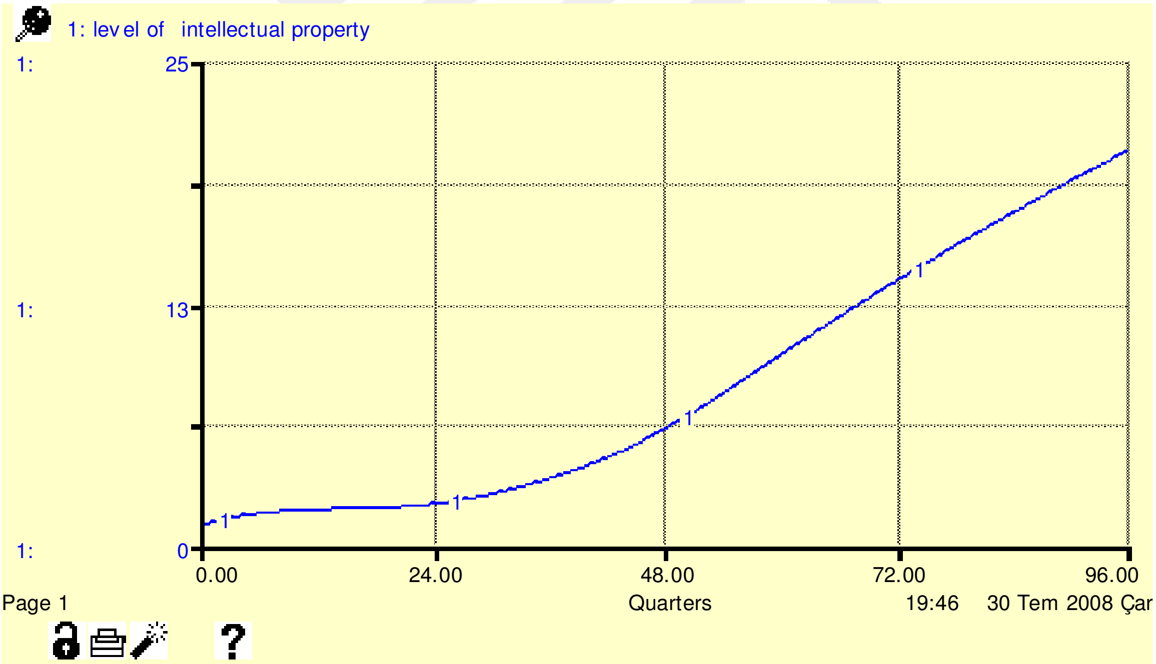

Figure 5.9 Base run of intellectual property

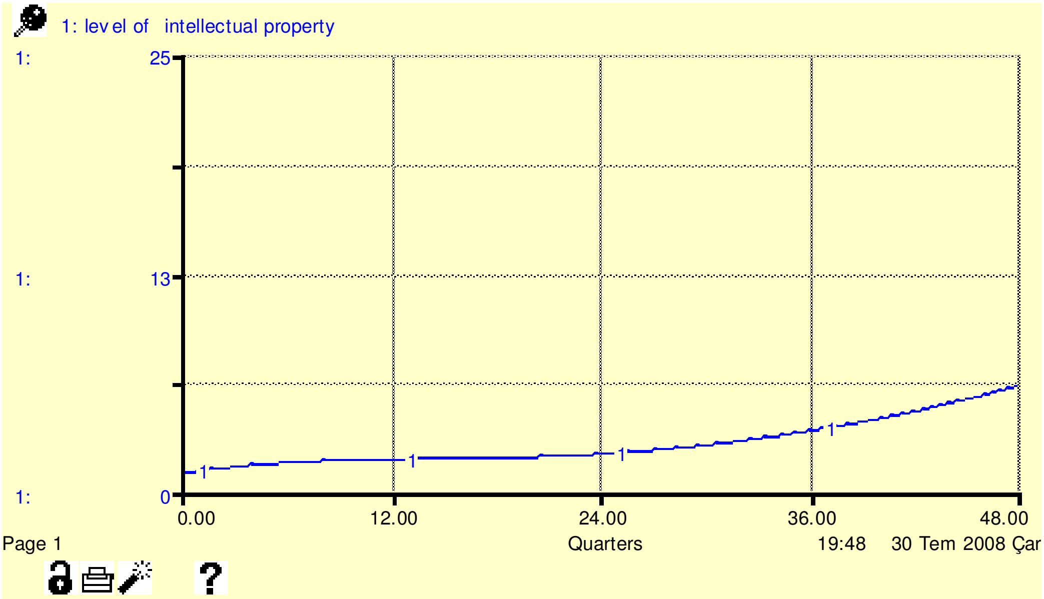

Figure 5.10a Base run of intellectual property

We have a pattern which is coherent with Arcelik's IP distribution, which can be seen in Figure 5.11 .There is a fluctuation here.

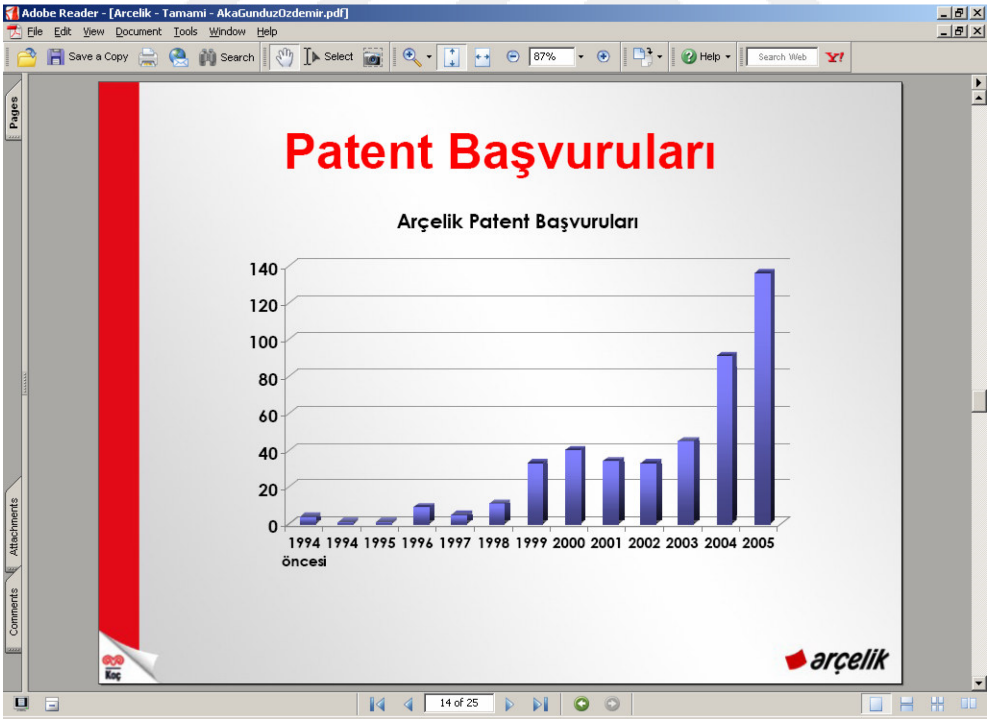

Figure 5 .10b Arcelik's intellectual property level (Özdemir, 2006)

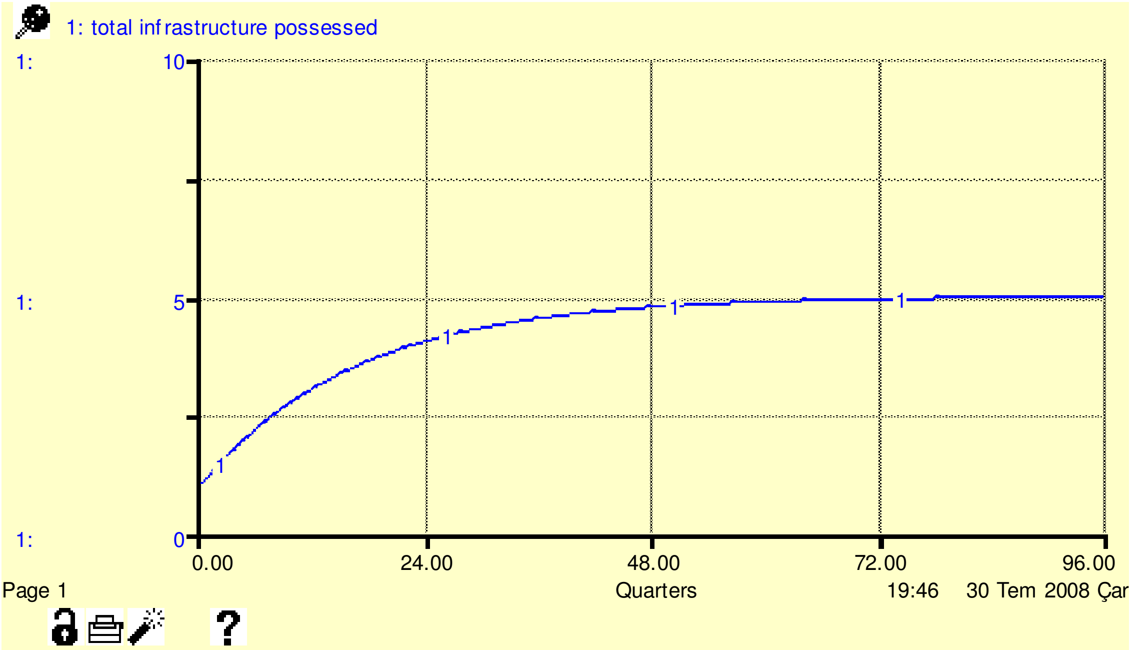

Figure 5.11 Base run of infrastructure

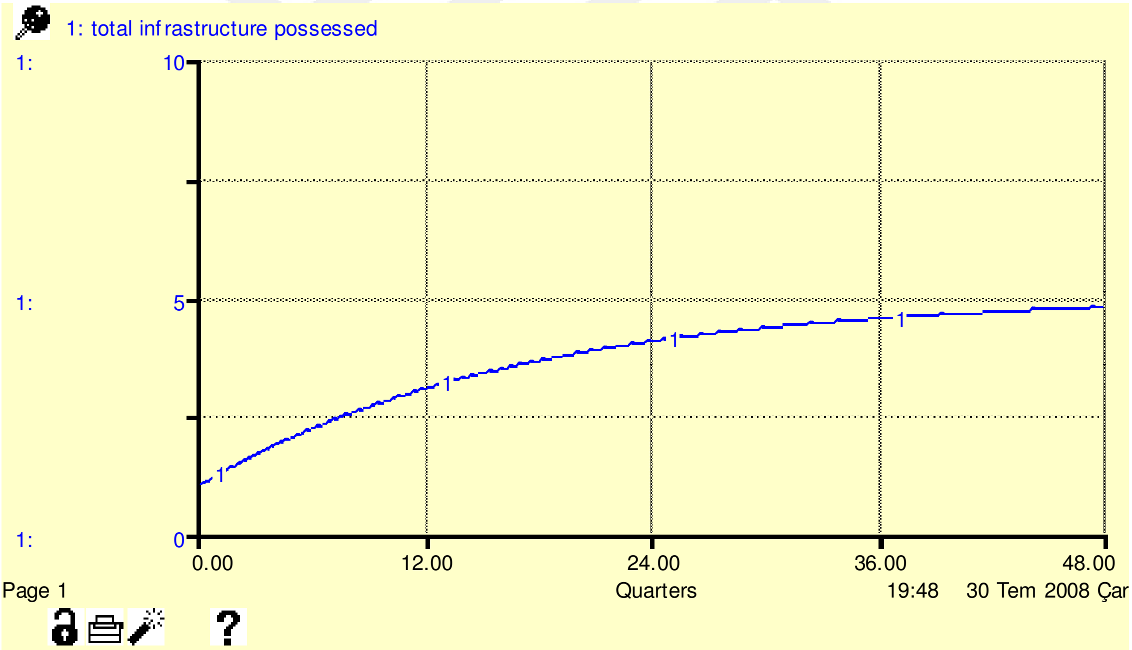

Figure 5.12 Base run of infrastructure

Infrastructure increases up to a certain point. After 9 years level of infrastructure becomes stable. The increase is not sufficient for the infrastructure. Infrastructure increases until the increase rate becomes equal with the decrease rate.

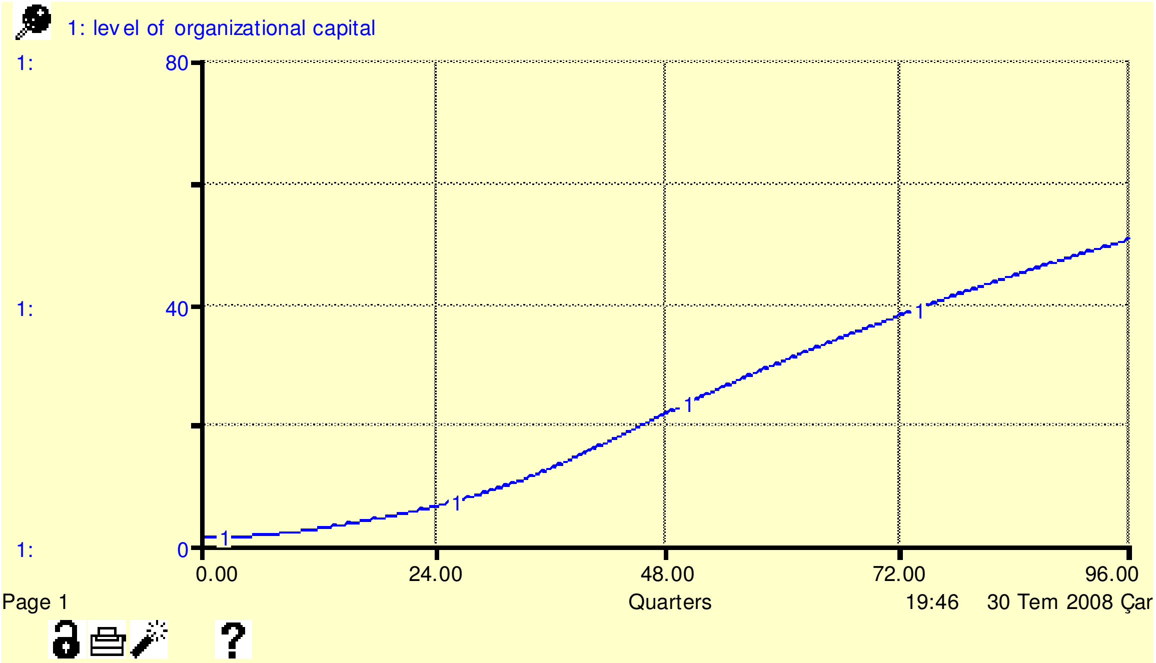

Figure 5.13 Base run of organizational capital

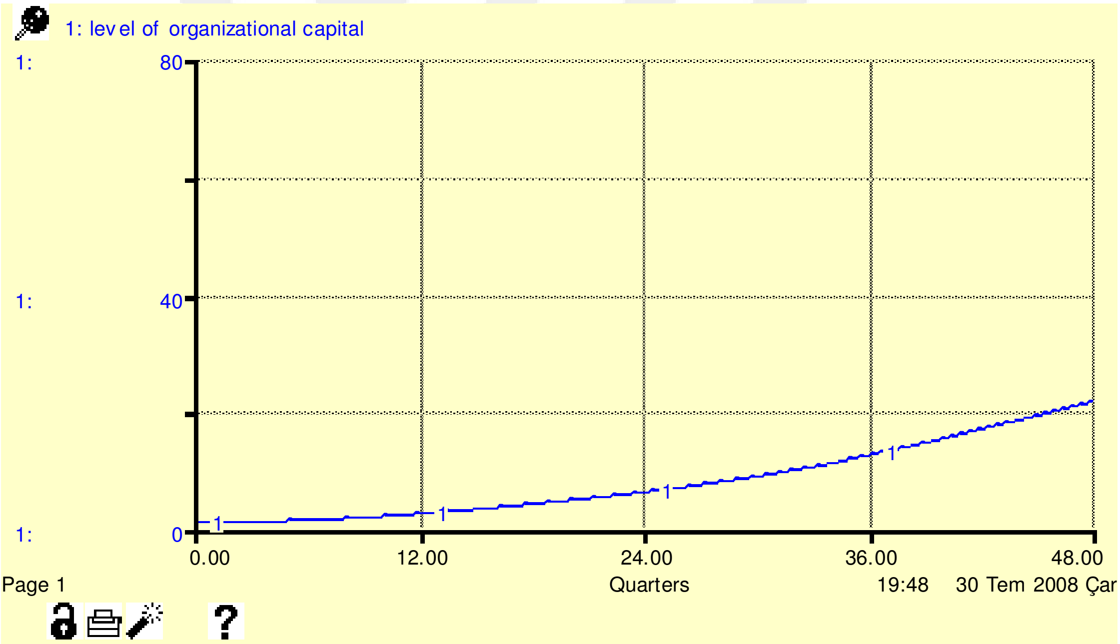

Figure 5.14 Base run of organizational capital

We see the same pattern of the IP in the organizational capital.

Table 5.3 Base run of the stocks

Base run of the stocks

15:22 08/08/2008 Table 1 (Base run of the stocks)

Quarters	level of intelle	level of organi	total infrastruc	motivation
4.0	1.48	1.10	1.86	1.01
8.0	1.71	1.59	2.53	1.05
12.0	1.81	2.42	3.06	1.12
16.0	1.86	3.46	3.47	1.20
20.0	1.93	4.68	3.80	1.31
24.0	2.09	6.09	4.06	1.43
28.0	2.40	7.79	4.26	1.57
32.0	2.85	9.84	4.42	1.73
36.0	3.42	12.36	4.54	1.90
40.0	4.13	15.29	4.64	2.08
44.0	4.98	18.42	4.72	2.28
Final	6.02	21.50	4.78	2.49

5.2 Validation

In system dynamics methodology, the model is tested step by step while building the stock and flow diagram. After building the model, validation tests should be applied in order to see, if the model is an adequate representation of the reality.

5.2.1 Extreme Conditions Test

Extreme conditions test concentrates on the behaviours of the model with the simulations carried out. This test includes simulation by giving extreme values to the selected variables. The behaviour of the system can be analyzed after this test and expected mode of the behaviour can be compared. Extreme condition test is relevant for this model. Parameters for this test are percentage budget on infrastructure, percentage budget on IP and percentage budget on reward.

5.2.1.1 Percentage budget on infrastructure is set at 0.

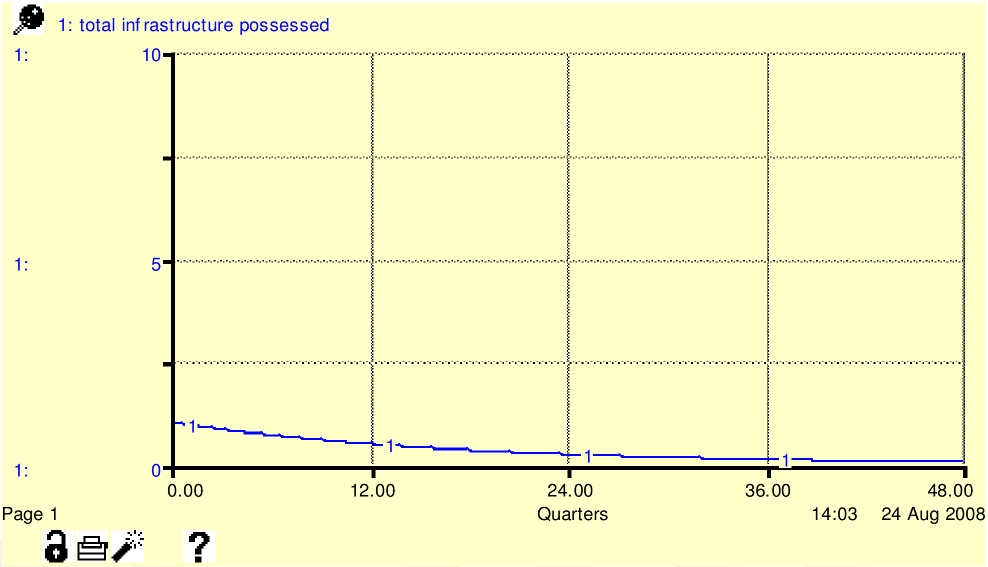

Figure 5.15 Total infrastructure

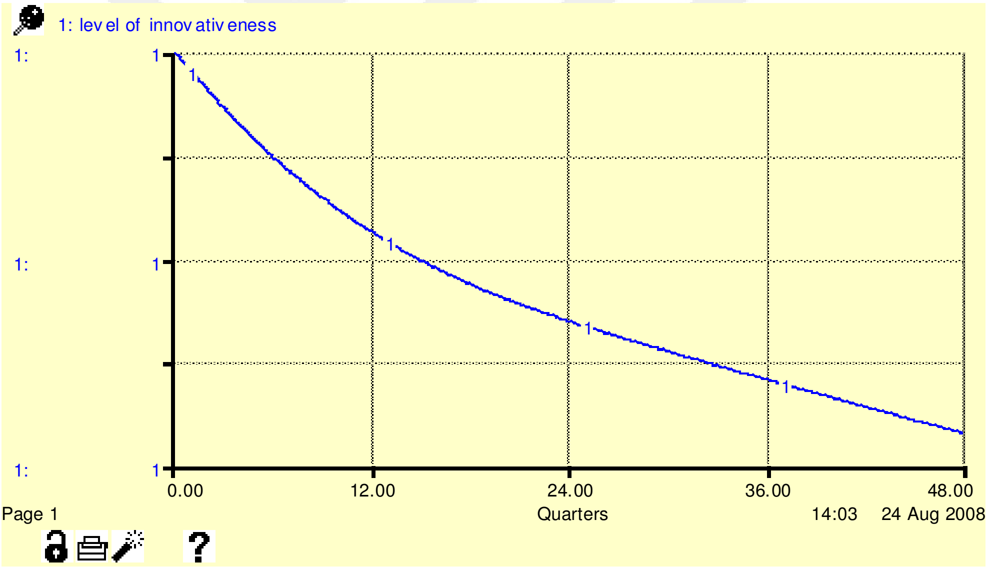

Figure 5.16 Level of innovativeness

Table 5.4 Stock values with extreme condition test

extreme case

14:03 24/08/2008 Table 5 (extreme case)

Quarters	total infrastru	level of innov
.0	1.00	1.00
4.0	0.79	0.96
8.0	0.62	0.94
12.0	0.49	0.91
16.0	0.38	0.89
20.0	0.30	0.88
24.0	0.24	0.87
28.0	0.19	0.86
32.0	0.15	0.85
36.0	0.11	0.84
40.0	0.09	0.83
44.0	0.07	0.82
Final	0.06	0.81

When percentage budget on infrastructure is set at 0, it is seen that total infrastructure goes to 0 in the 48 quarters as it is expected. In this model, the main stock variable is innovativeness as it is known. Innovativeness also declines when the percentage budget on infrastructure is 0.

5.2.1.2 Percentage intellectual property purchase is set at 0.

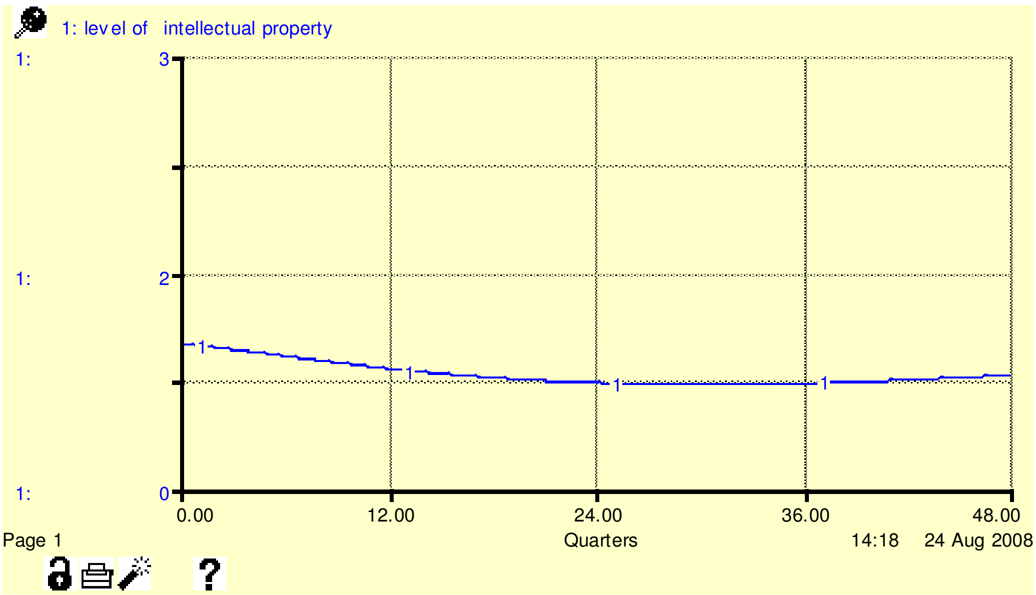

Figure 5.17 Level of intellectual property

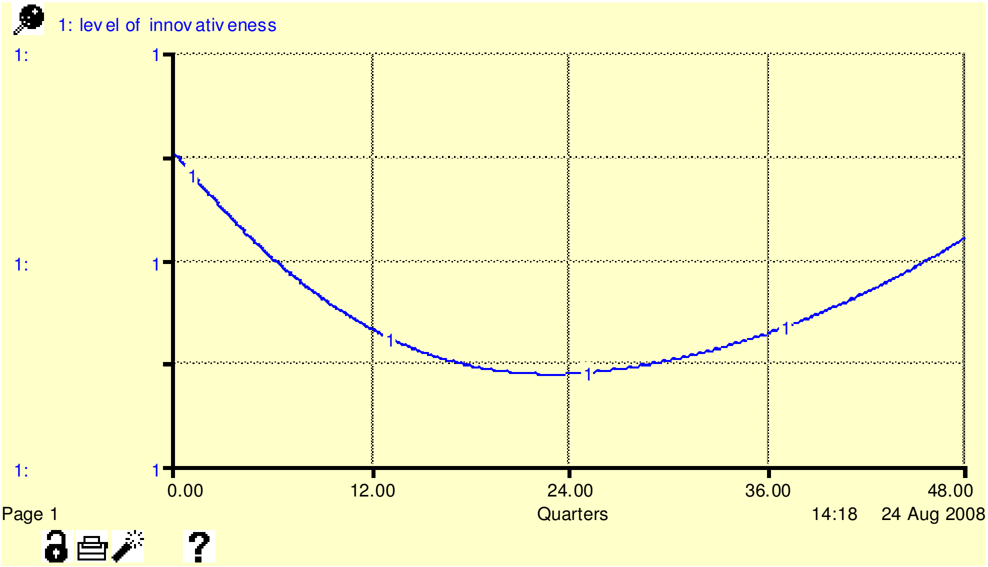

Figure 5.18 Level of innovativeness

Table 5.5 Stock values with the extreme conditions test

extreme case

14:18 24/08/2008 Table 6 (extreme case)

Quarters	level of intel	level of innov
.0	1.00	1.00
4.0	0.94	0.96
8.0	0.88	0.94
12.0	0.83	0.92
16.0	0.78	0.90
20.0	0.75	0.90
24.0	0.73	0.89
28.0	0.72	0.90
32.0	0.72	0.90
36.0	0.73	0.91
40.0	0.74	0.93
44.0	0.76	0.94
Final	0.78	0.96

In the model, IP can be obtained by purchasing and R&D. In this case, IP can be obtained only through research and development department as the percentage budget on IP is set at 0. It is seen that IP declines.

5.2.1.3 Percentage reward budget is set at 0.

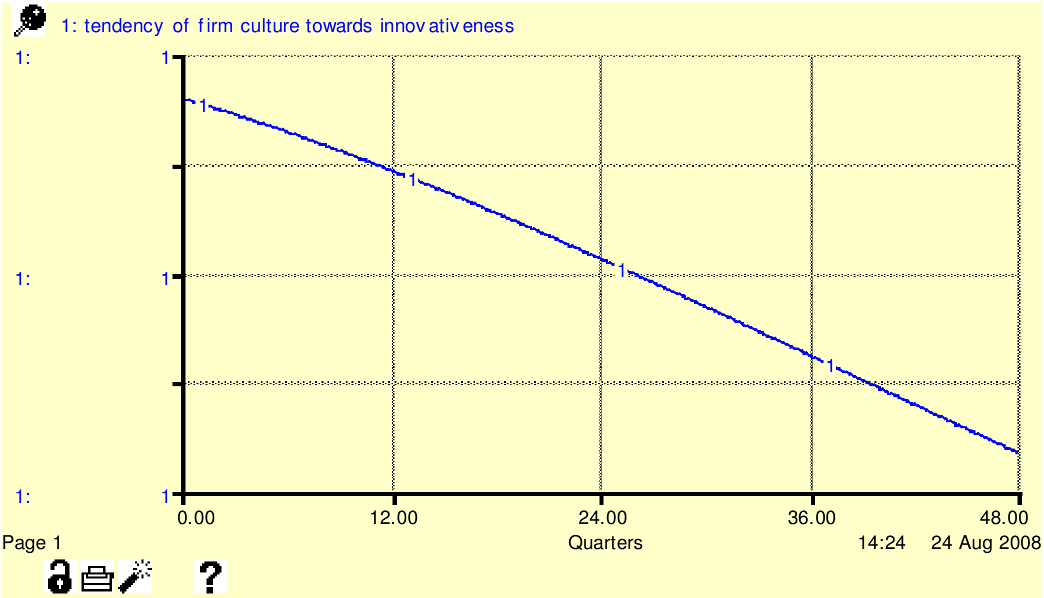

Figure 5.19 Firm culture

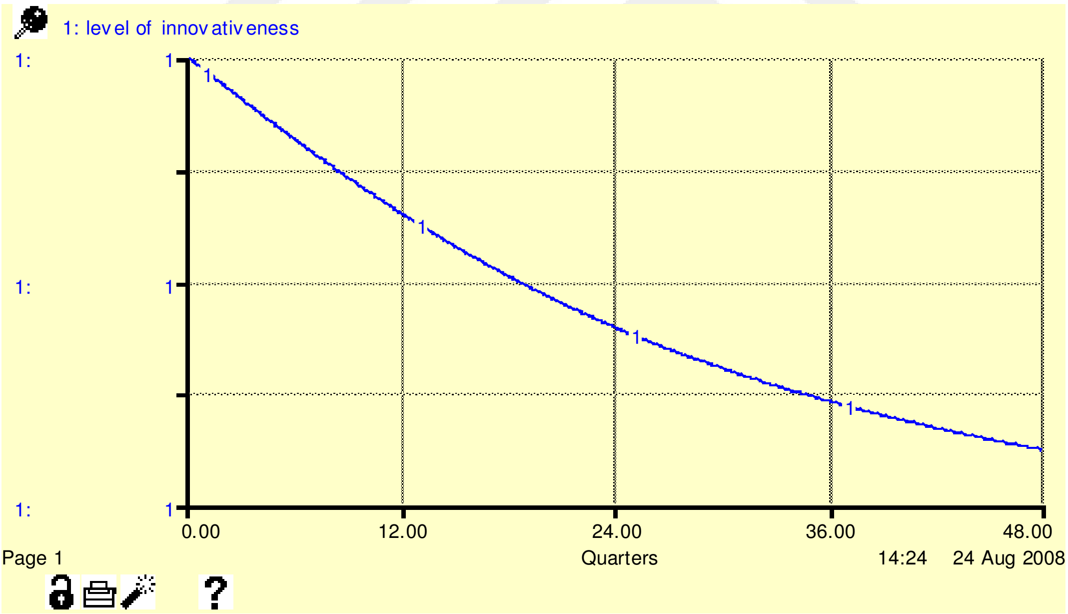

Figure 5.20 Level of innovativeness

Table 5.6 Stock values with extreme conditions test

extreme case

14:24 24/08/2008 Table 7 (extreme case)

Quarters	tendency of	level of innov
4.0	1.00	0.96
8.0	0.99	0.93
12.0	0.99	0.89
16.0	0.99	0.87
20.0	0.99	0.84
24.0	0.98	0.82
28.0	0.98	0.80
32.0	0.97	0.78
36.0	0.97	0.77
40.0	0.97	0.76
44.0	0.96	0.75
Final	0.96	0.74

When the percentage budget on reward is set at 0, we see that firm culture and innovativeness decreases. In the model there are other variables which increase the level of innovativeness. That's why it is normal to see that innovativeness value is not 0.

5.2.1.4 Percentage of reward budget is taken as 1 and the others as 0.

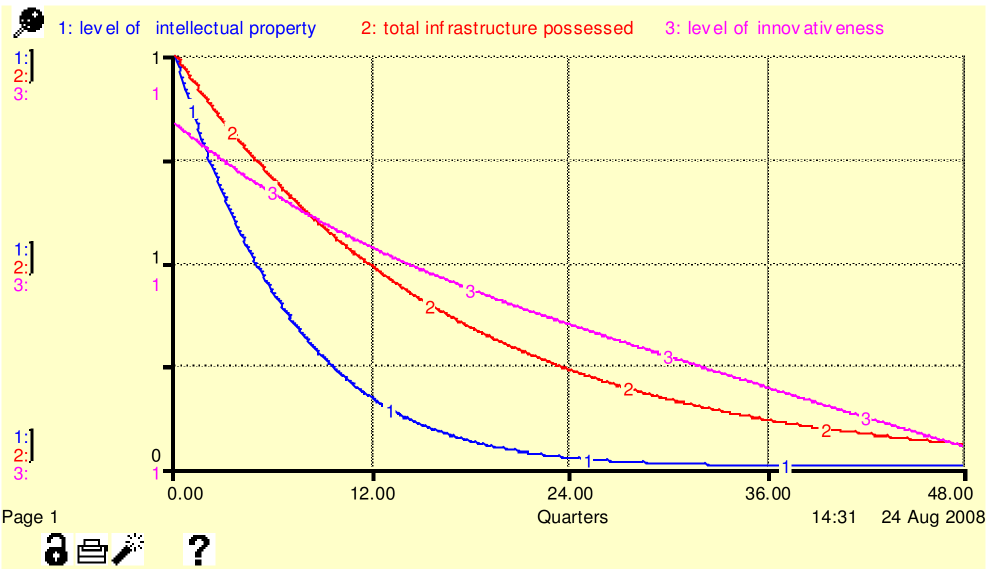

Figure 5.21 Extreme condition test of percentage of reward budget

5.2.1.5 Percentage for intellectual property purchase is taken as 1.

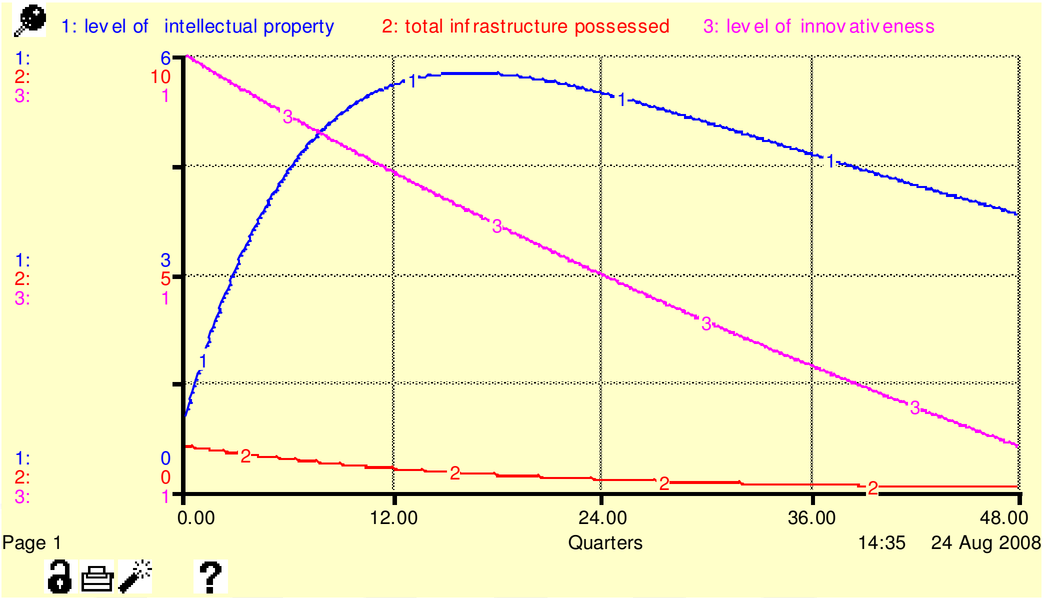

Figure 5.22 Extreme condition test of percentage for intellectual property purchase

When percentage of IP purchase is 1, level of IP increases at a certain level but innovativeness decreases in the long run.

5.2.1.6 Percentage of infrastructure budget is taken as 1 the results are below.

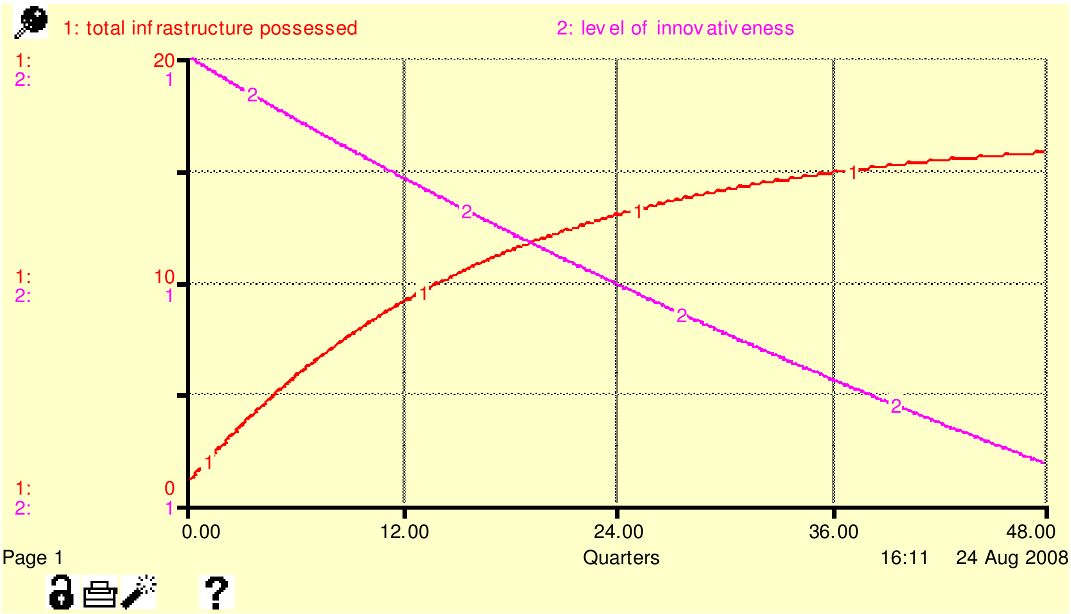

Figure 5.23 Extreme condition test of percentage budget on infrastructure

In this case, infrastructure increases significantly but in the long run innovativeness can not increase.

5.2.1.7 Percentage of reward budget and infrastructure are taken as 0.25 and 0.75 respectively.

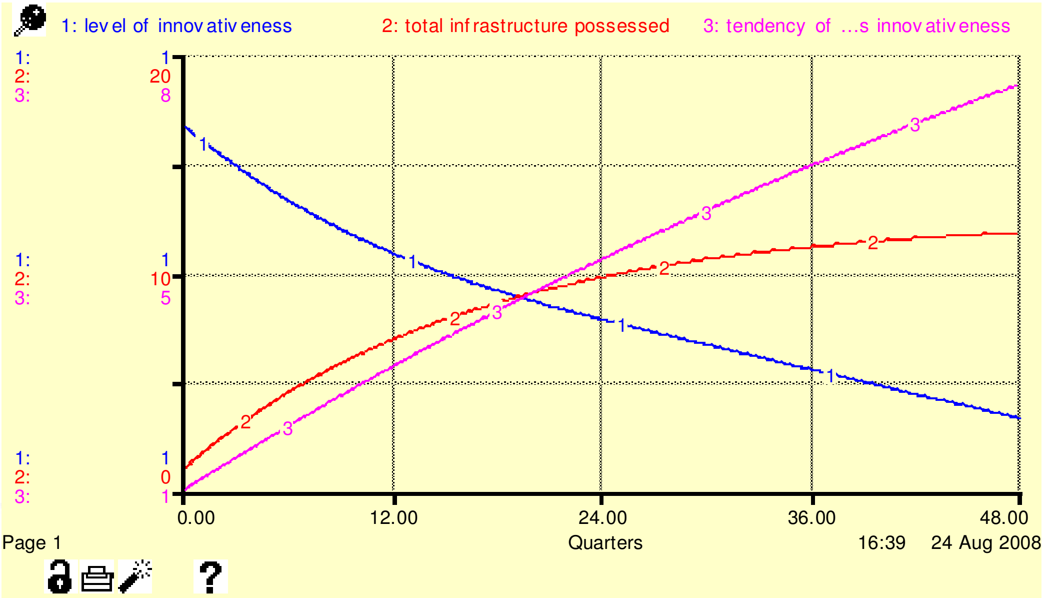

Figure 5.24 Extreme case for R&D and intellectual property purchase

It is seen that in order to be innovative in the long run, focusing on specific resource is not an efficient way.

5.2.1.8 Percentage for intellectual property purchase and infrastructure are taken as 0.4 and 0.6 respectively.

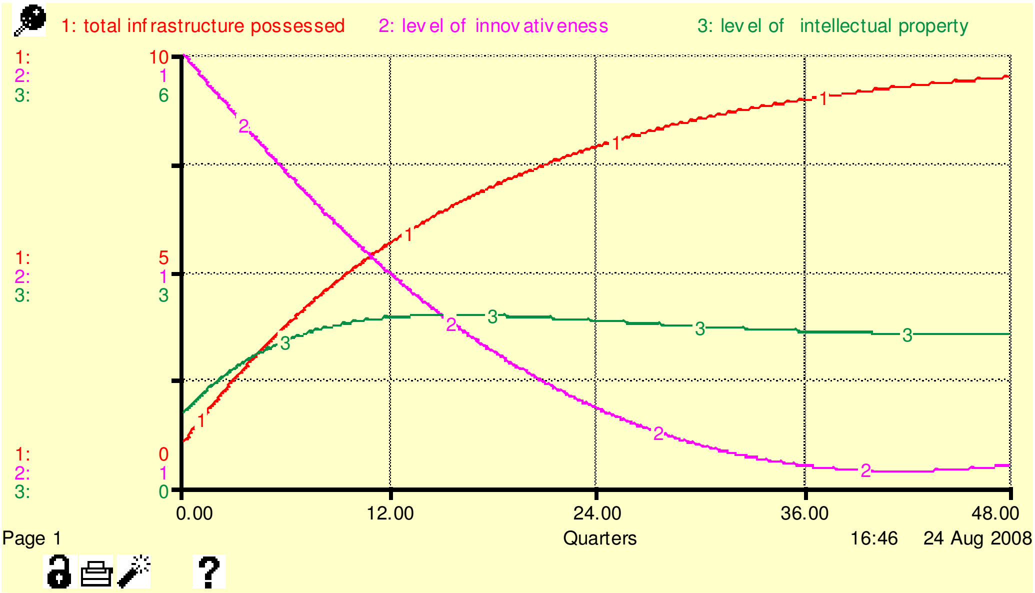

Figure 5.25 Extreme case for reward and R&D

5.2.1.9 Percentage for R&D and infrastructure are taken 0.

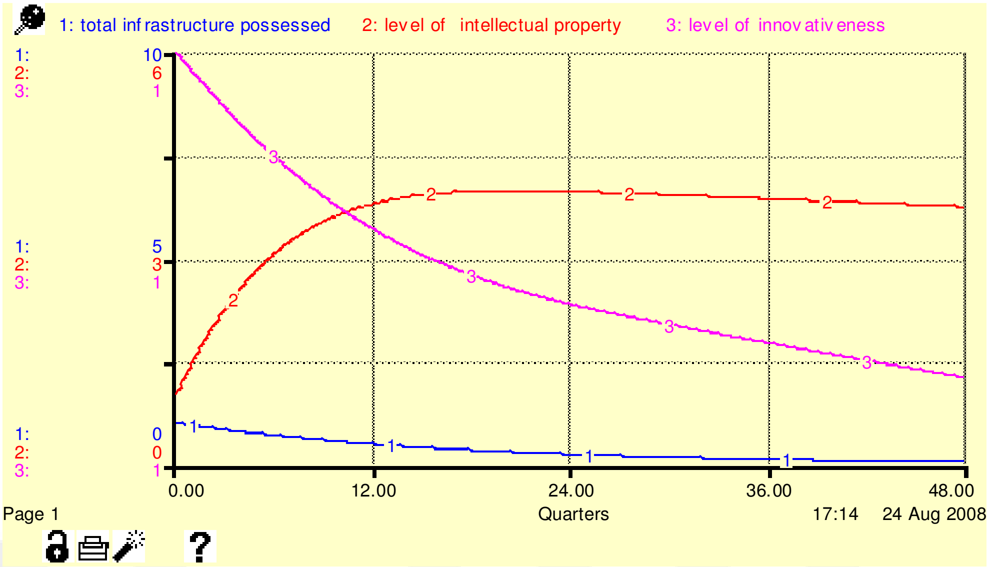

Figure 5.26 Extreme case for R&D and infrastructure

IP can increase at a certain point by the percentage for IP purchase but infrastructure declines.

5.2.1.10 Percentage of IP and and reward are taken 0 the results are below.

Figure 5.27 Extreme case for intellectual property purchase and reward

It is seen that innovativeness, IP and firm culture decreases significantly.

5.2.1.11 Percentage IP purchase and infrastructure are taken as 0 the results are below.

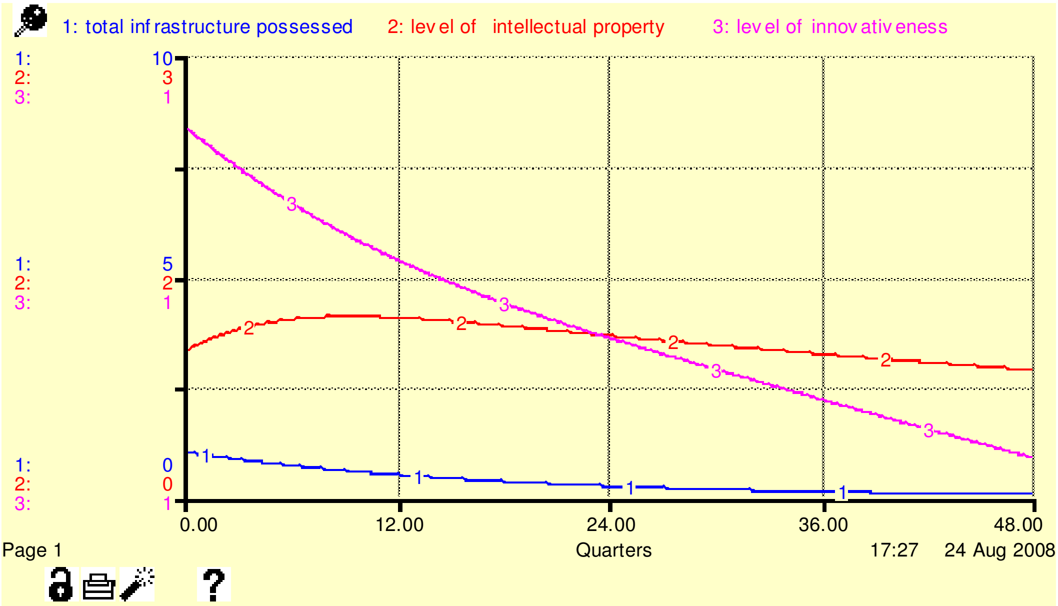

Figure 5.28 Extreme case for IP and infrastructure

It is seen that, IP increases by the help of R&D then declines. Also, infrastructure and innovativeness decrease because of the extreme values.

5.2.1.12 Percentage of reward budget and infrastructure are taken as 0.

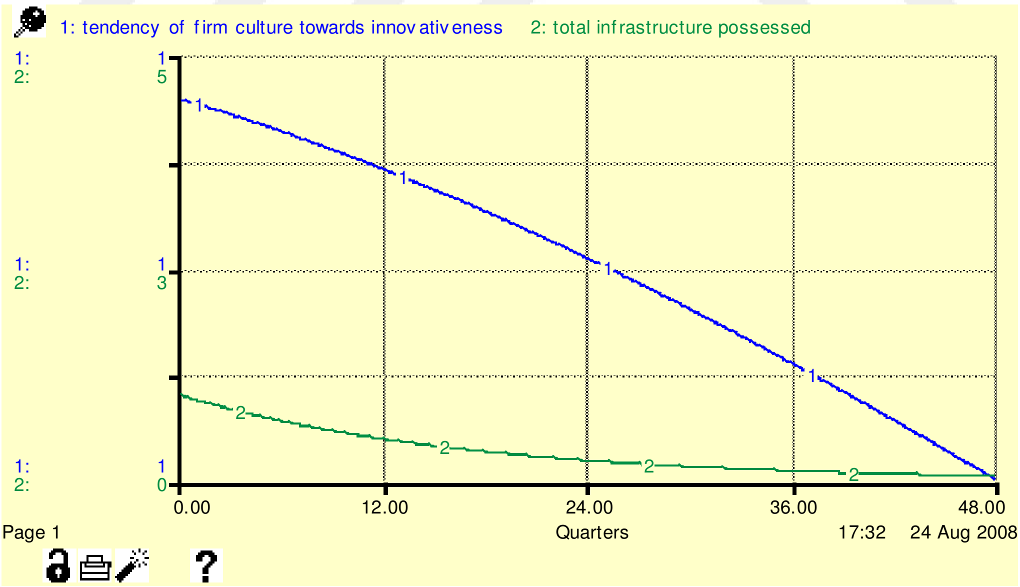

Figure 5.29 Extreme case for percentage of reward and infrastructure

Infrastructure and level of firm culture decreases when percentages are taken as 0.In this test, it is seen that the model results are sensible with the extreme values. When the selected parameters are taken as 0, innovativeness decreases as it is expected.

5.3 Sensitivity Analysis

Sensitivity analysis controls the robustness of the model to uncertainty. Sensitivity analysis states how and to what extent the behaviour of the model changes as a result of changes in the parameters.

5.3.1 Firm culture decrease fraction changes between 0.01-0.1 with equal intervals for 20 runs.

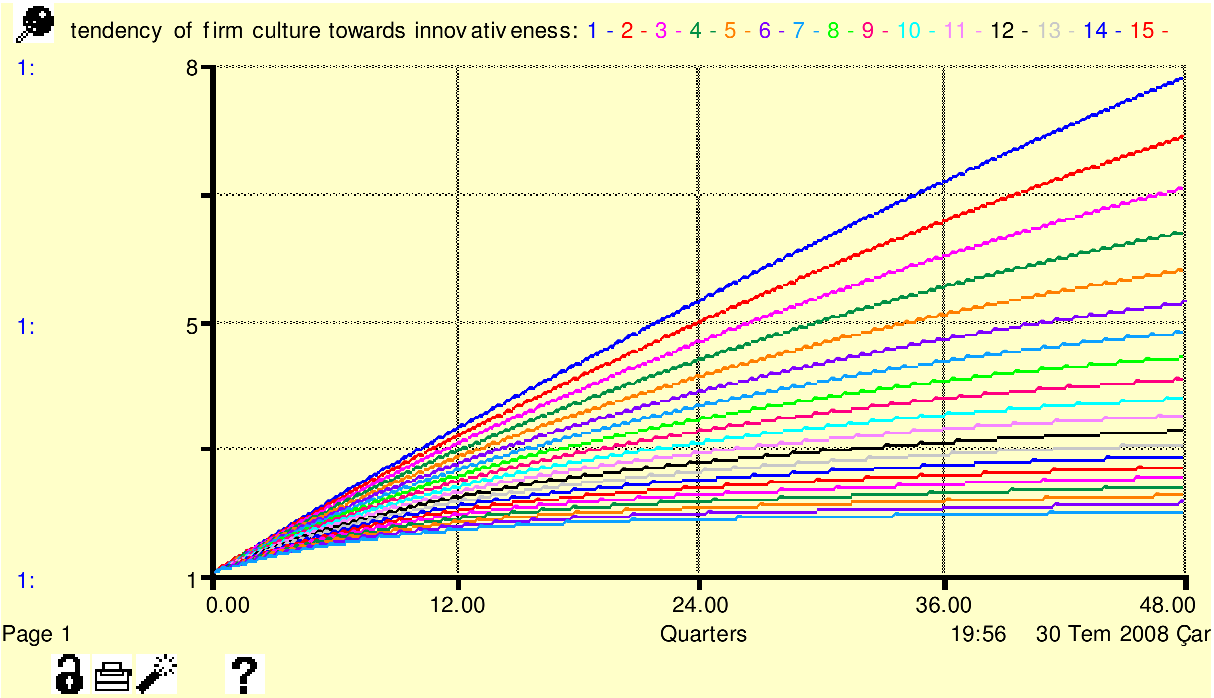

Figure 5.30 Firm culture

We see that firm culture decrease fraction is a critical variable. When the decrease fraction of the firm culture is 0.01 firm culture increases significantly, but if the fraction is high, firm culture level can not increase itself as much.

Table 5.7 Firm culture decrease fraction

Firm culture

16:08 07/08/2008 Table 2 (Firm culture)

Quarters	1: tendency (	2: tendency (	3: tendency (	4: tendency (	5: tendency (
4.0	1.69	1.58	1.47	1.38	1.29
8.0	2.35	2.08	1.85	1.65	1.47
12.0	2.98	2.52	2.14	1.84	1.59
16.0	3.58	2.90	2.37	1.97	1.66
20.0	4.17	3.23	2.56	2.07	1.71
24.0	4.75	3.54	2.72	2.15	1.74
28.0	5.31	3.82	2.85	2.21	1.76
32.0	5.85	4.07	2.97	2.26	1.78
36.0	6.38	4.30	3.07	2.31	1.79
40.0	6.88	4.49	3.15	2.35	1.81
44.0	7.36	4.67	3.22	2.38	1.83
Final	7.84	4.82	3.27	2.41	1.85

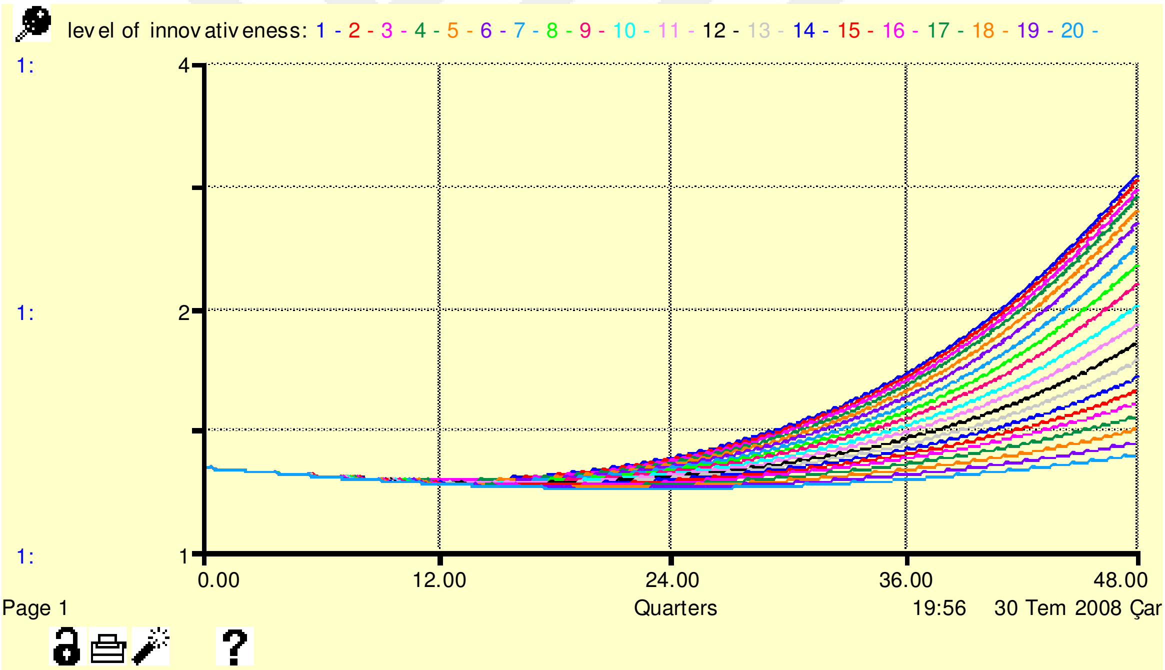

Figure 5.31 Level of innovativeness

Change in the firm culture decrease fraction affects innovation after 3 years. There is a phase difference for the level of innovativeness. Also when the decrease fraction of the firm culture is high, innovativeness can not increase.

Table 5.8 Level of innovativeness

Level of innovativeness

16:48 07/08/2008 Table 3 (Level of innovativeness)

Quarters	1: level of inr	2: level of inr	3: level of inr	4: level of inr	5: level of inr
.0	1.00	1.00	1.00	1.00	1.00
4.0	0.96	0.96	0.96	0.96	0.96
8.0	0.94	0.94	0.93	0.93	0.93
12.0	0.93	0.92	0.91	0.91	0.90
16.0	0.94	0.92	0.91	0.90	0.88
20.0	0.98	0.95	0.92	0.90	0.87
24.0	1.06	1.01	0.96	0.92	0.87
28.0	1.18	1.11	1.02	0.95	0.88
32.0	1.34	1.24	1.11	1.00	0.90
36.0	1.57	1.44	1.24	1.07	0.93
40.0	1.88	1.70	1.41	1.17	0.97
44.0	2.28	2.06	1.63	1.29	1.02
Final	2.80	2.52	1.93	1.44	1.08

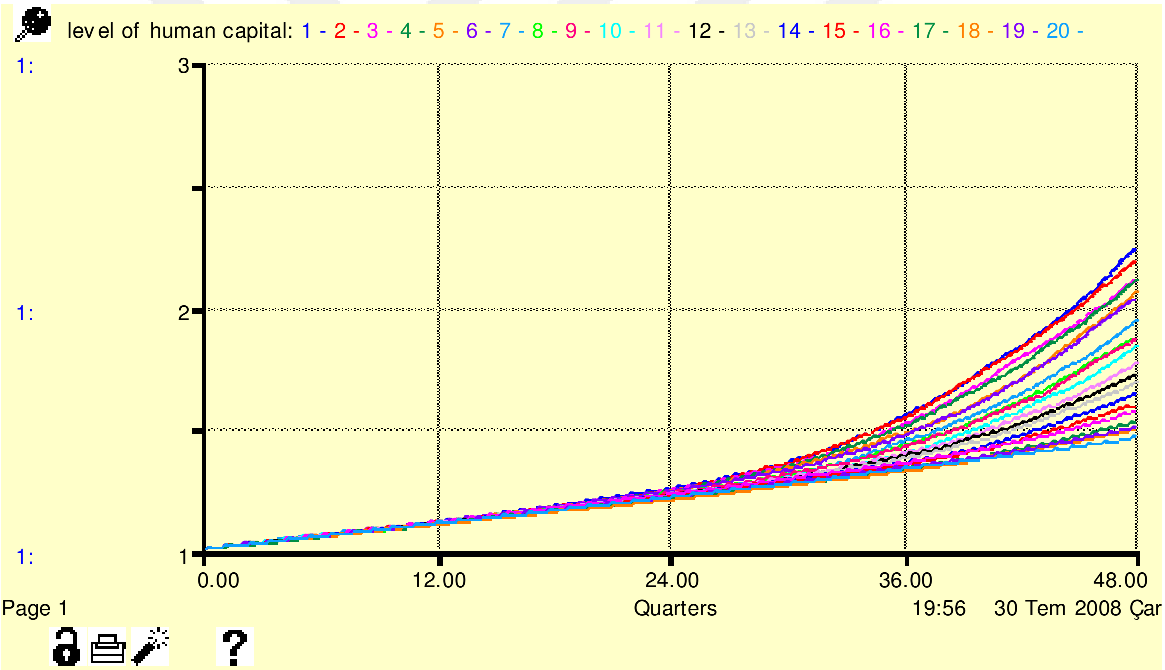

Figure 5.32 Level of human capital

Firm culture decrease fraction affects human capital after 3 years. Phase difference can be seen here.

Table 5.9 Human capital

Human capital

17:21 07/08/2008 Table 4 (Human capital)

Quarters	1: level of hu	2: level of hu	3: level of hu	4: level of hu	5: level of hu
.0	1.00	1.00	1.00	1.00	1.00
4.0	1.03	1.04	1.04	1.03	1.04
8.0	1.07	1.07	1.07	1.07	1.07
12.0	1.10	1.11	1.11	1.10	1.10
16.0	1.14	1.15	1.15	1.14	1.14
20.0	1.18	1.18	1.19	1.17	1.17
24.0	1.23	1.22	1.23	1.21	1.21
28.0	1.30	1.28	1.27	1.25	1.25
32.0	1.39	1.35	1.32	1.30	1.28
36.0	1.52	1.46	1.40	1.35	1.32
40.0	1.71	1.59	1.49	1.41	1.36
44.0	1.93	1.78	1.62	1.49	1.40
Final	2.19	2.02	1.79	1.59	1.46

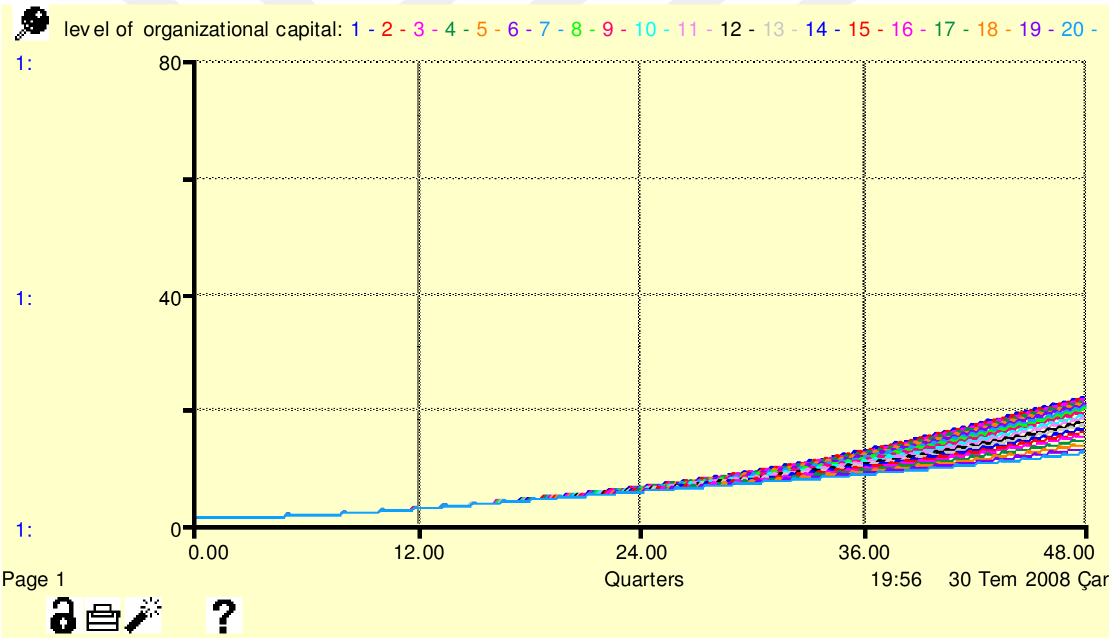

Figure 5.33 Level of organizational capital

In the model firm culture does not have a direct effect towards organizational capital. But, there is an indirect effect, which occurs after 6 years.

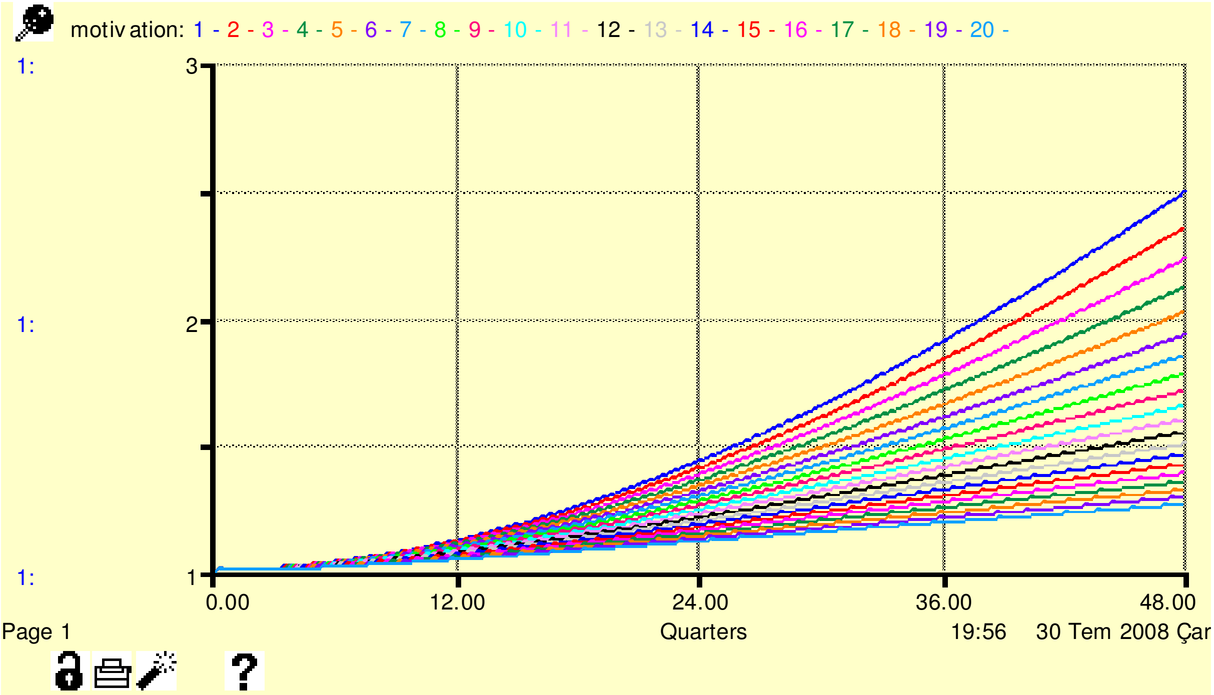

Figure 5.34 Motivation

It is clear that firm culture plays an important role in the level of innovativeness, which is also mentioned in the literature. In the model, firm culture has a direct effect on motivation. Sensitivity analysis also shows that motivation is sensitive with the firm culture decrease fraction.

Table 5.10 Motivation

Motivation

17:21 07/08/2008 Table 5 (Motivation)

Quarters	1: motivation	2: motivation	3: motivation	4: motivation	5: motivation
.0	1.00	1.00	1.00	1.00	1.00
4.0	1.01	1.01	1.01	1.01	1.01
8.0	1.05	1.04	1.04	1.03	1.02
12.0	1.12	1.09	1.07	1.06	1.04
16.0	1.20	1.16	1.12	1.09	1.06
20.0	1.31	1.23	1.17	1.13	1.09
24.0	1.43	1.32	1.23	1.16	1.11
28.0	1.57	1.41	1.29	1.20	1.14
32.0	1.73	1.51	1.35	1.24	1.16
36.0	1.90	1.61	1.42	1.29	1.19
40.0	2.08	1.72	1.49	1.33	1.21
44.0	2.28	1.83	1.55	1.37	1.24
Final	2.49	1.95	1.62	1.41	1.26

We can infer that firm culture decrease fraction has a significant effect on motivation.

5.3.2 Initial value of the firm culture changes between 0-2 with equal intervals for 10 runs. The results are below.

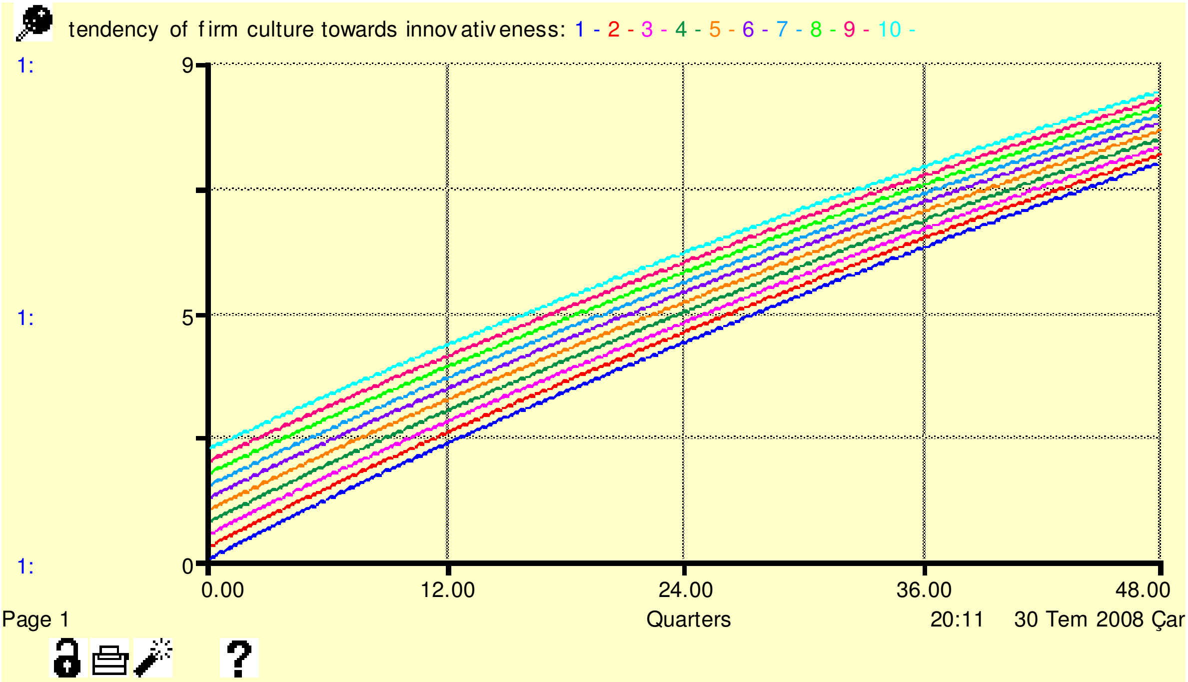

Figure 5.35 Firm culture

Here we see that firm culture stock starts with a better level and reaches a better point.

Table 5.11 Firm culture initial value

Firm culture inital value

15:47 08/08/2008 Table 1: p2 (Firm culture inital value)

Quarters	1: tendency	2: tendency	3: tendency	4: tendency	5: tendency
.0	0.00	0.50	1.00	1.50	2.00
4.0	0.73	1.21	1.69	2.17	2.66
8.0	1.43	1.89	2.35	2.82	3.28
12.0	2.09	2.53	2.98	3.43	3.88
16.0	2.72	3.15	3.58	4.02	4.45
20.0	3.33	3.75	4.17	4.59	5.01
24.0	3.92	4.33	4.75	5.15	5.56
28.0	4.51	4.91	5.31	5.70	6.09
32.0	5.08	5.47	5.85	6.23	6.61
36.0	5.64	6.01	6.38	6.74	7.10
40.0	6.17	6.53	6.88	7.23	7.58
44.0	6.68	7.02	7.37	7.70	8.04
Final	7.18	7.51	7.84	8.16	8.48

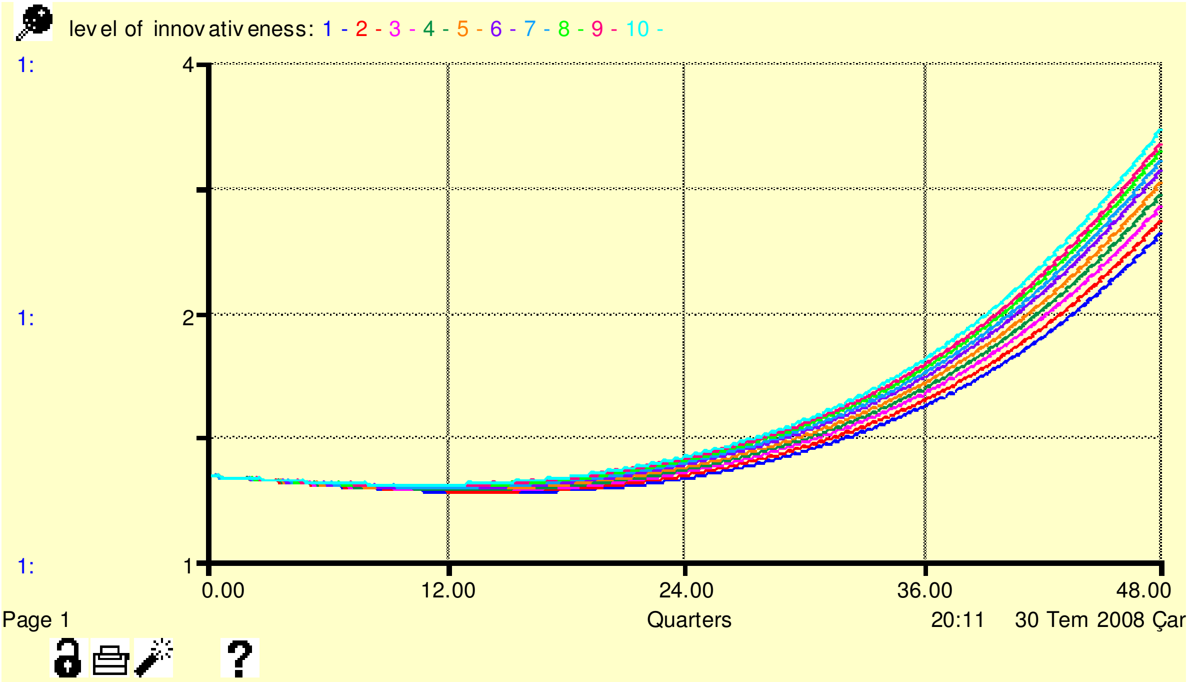

Figure 5.36 Level of Innovativeness

The initial value of the firm culture affects level of innovativeness after 3 years. Innovativeness starts to be affected by the initial value of the firm culture between 12-24 quarters.

Table 5.12 Level of innovativeness

Level of innovativeness
15:50 08/08/2008 Table 2 (Level of innovativeness)

Quarters	1: level of inr	2: level of inr	3: level of inr	4: level of inr	5: level of inr
.0	1.00	1.00	1.00	1.00	1.00
4.0	0.96	0.96	0.96	0.97	0.97
8.0	0.93	0.93	0.94	0.95	0.95
12.0	0.90	0.91	0.93	0.94	0.95
16.0	0.90	0.92	0.94	0.96	0.97
20.0	0.93	0.96	0.98	1.01	1.02
24.0	0.99	1.02	1.06	1.09	1.11
28.0	1.08	1.13	1.18	1.22	1.25
32.0	1.22	1.29	1.34	1.39	1.43
36.0	1.41	1.50	1.57	1.64	1.69
36.0	[illegible]	[illegible]	1.67	[illegible]	1.60
44.0	2.01	2.16	2.28	2.41	2.48
Final	2.45	2.64	2.80	2.95	3.05

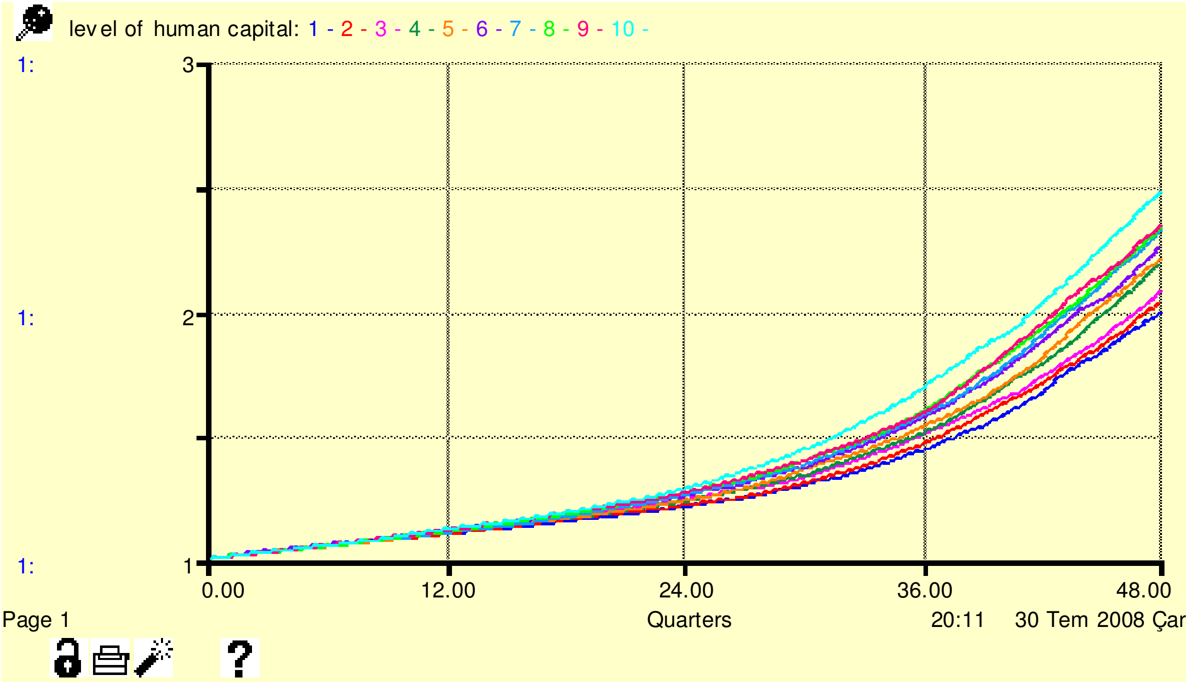

Figure 5.37 Level of human capital

On the other hand, initial value of the firm culture affects human capital after 18 quarters.

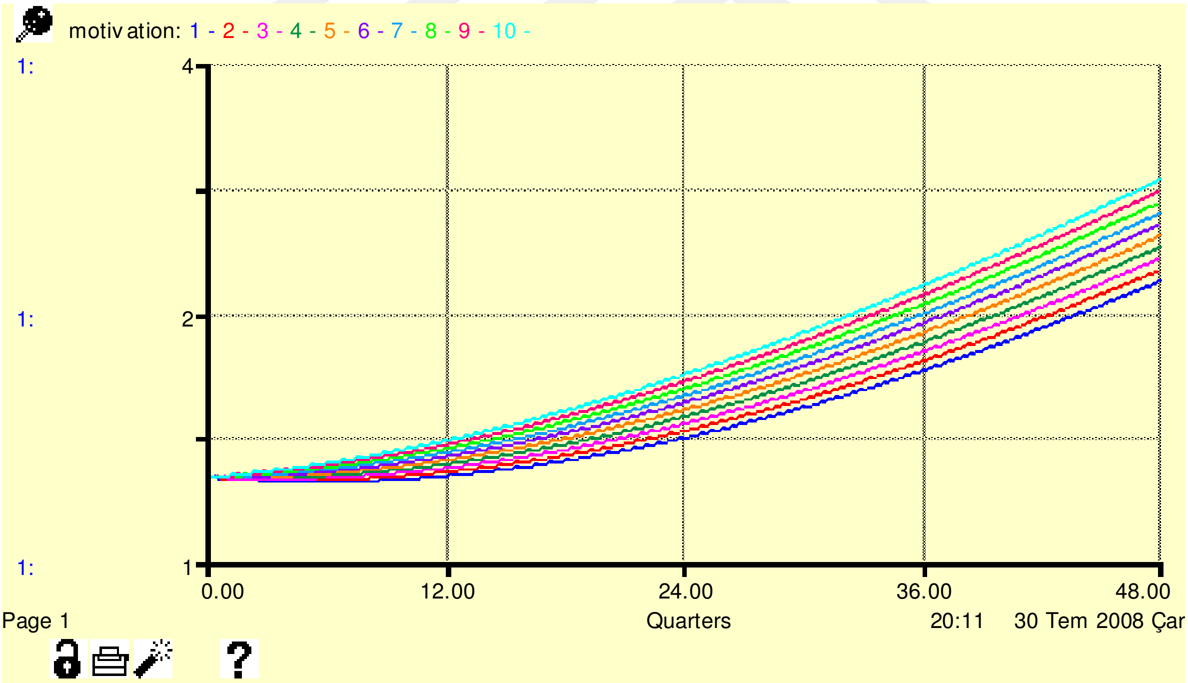

Figure 5.38 Motivation

Initial value of firm culture affects motivation from the beginning. Motivation reaches a better value when the initial level of firm culture is high.

5.3.3 Initial value of innovativeness changes between 0-2 with equal intervals for 5 runs.

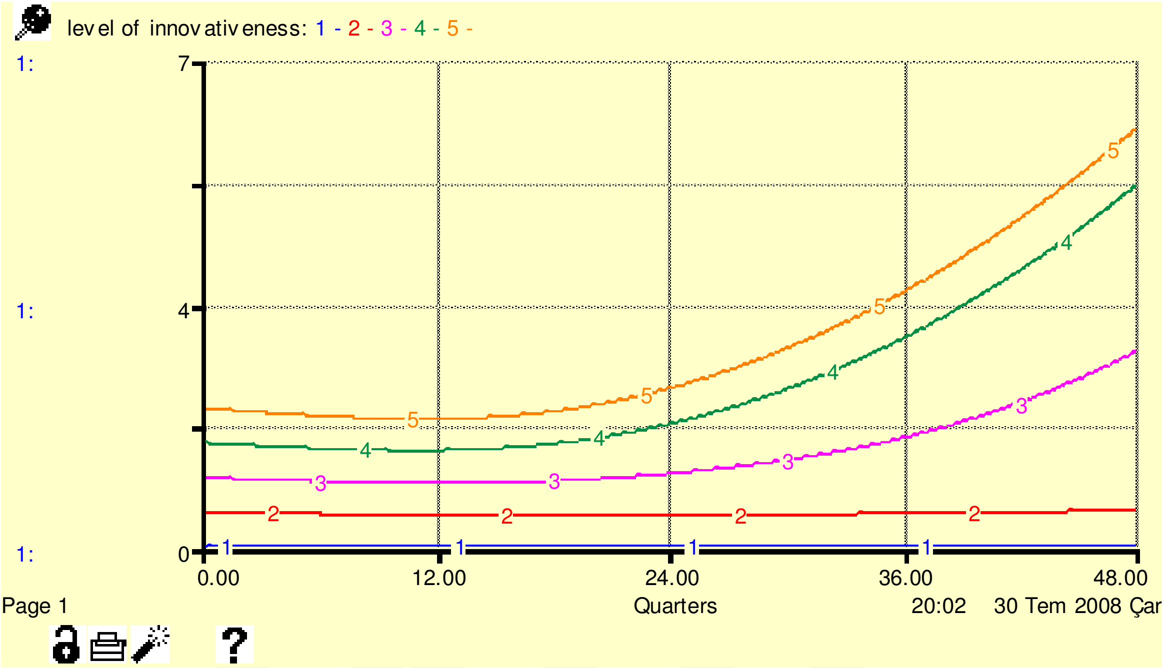

Figure 5.39 Level of innovativeness

It is seen that the initial level of the innovativeness plays an important role. When the initial value of the level of innovativeness is less than the reference level value, innovativeness can not manage to increase. At this point firms should take advisory for the future of the company.

Table 5.13 Level of innovativeness

Innovativeness
17:29 07/08/2008 Table 3 (Innovativeness)

Quarters	1: level of inr	2: level of inr	3: level of inr	4: level of inr	5: level of inr
.0	0.00	0.50	1.00	1.50	2.00
4.0	0.00	0.49	0.97	1.45	1.94
8.0	0.01	0.48	0.96	1.43	1.90
12.0	0.01	0.49	0.98	1.46	1.93
16.0	0.01	0.50	1.04	1.58	2.05
20.0	0.01	0.52	1.16	1.82	2.31
24.0	0.01	0.54	1.36	2.18	2.69
28.0	0.02	0.57	1.64	2.67	3.19
32.0	0.02	0.60	2.01	3.25	3.80
36.0	0.02	0.64	2.50	3.94	4.50
40.0	0.02	0.68	3.10	4.72	5.29
44.0	0.02	0.73	3.79	5.58	6.16
48.0	0.02	0.80	4.58	6.52	7.11

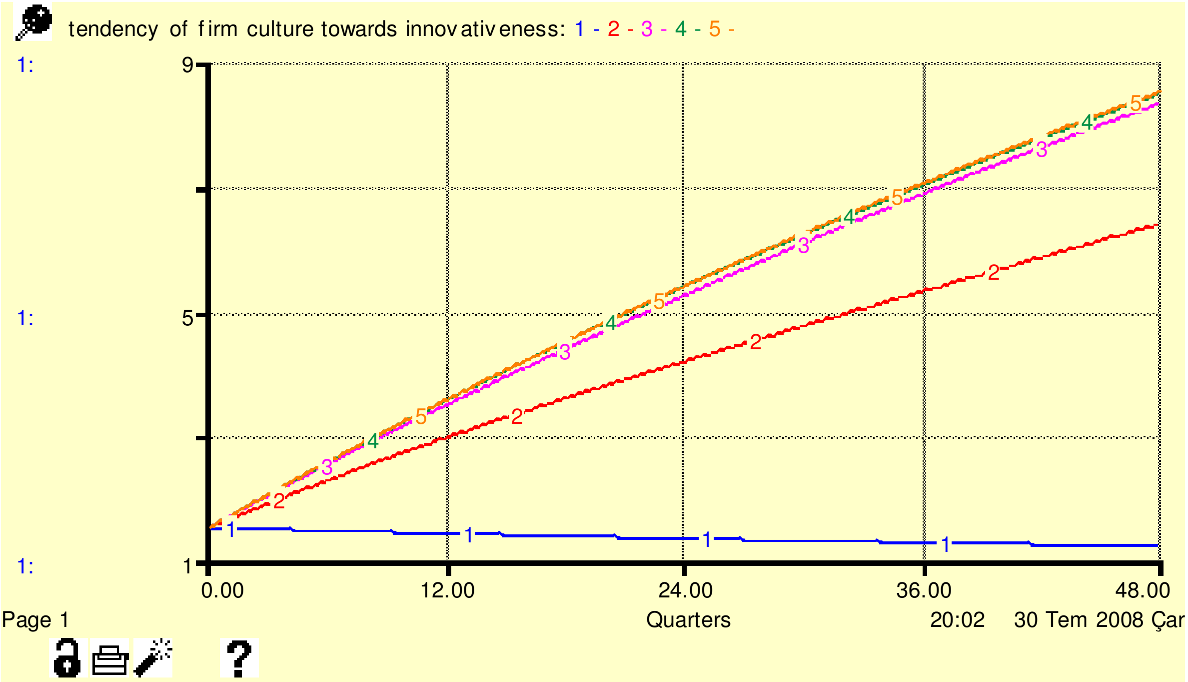

Figure 5.40 Firm culture

The same results can be seen in the firm culture. When initial value of innovativeness is zero, it is seen that firm culture also decreases deeply.

Table 5.14 Firm culture

Firm culture

16:07 08/08/2008 Table 3 (Firm culture)

Quarters	1: tendency	2: tendency	3: tendency	4: tendency	5: tendency
.0	1.00	1.00	1.00	1.00	1.00
4.0	0.97	1.52	1.69	1.71	1.72
8.0	0.94	2.01	2.36	2.40	2.40
12.0	0.91	2.49	2.99	3.06	3.06
16.0	0.88	2.95	3.61	3.69	3.70
20.0	0.86	3.40	4.22	4.30	4.31
24.0	0.84	3.85	4.80	4.89	4.90
28.0	0.82	4.30	5.37	5.45	5.47
32.0	0.80	4.74	5.91	6.00	6.02
36.0	0.78	5.18	6.44	6.53	6.55
40.0	0.76	5.62	6.95	7.04	7.06
44.0	0.74	6.05	7.44	7.54	7.56
48.0	0.73	6.49	7.92	8.01	8.03

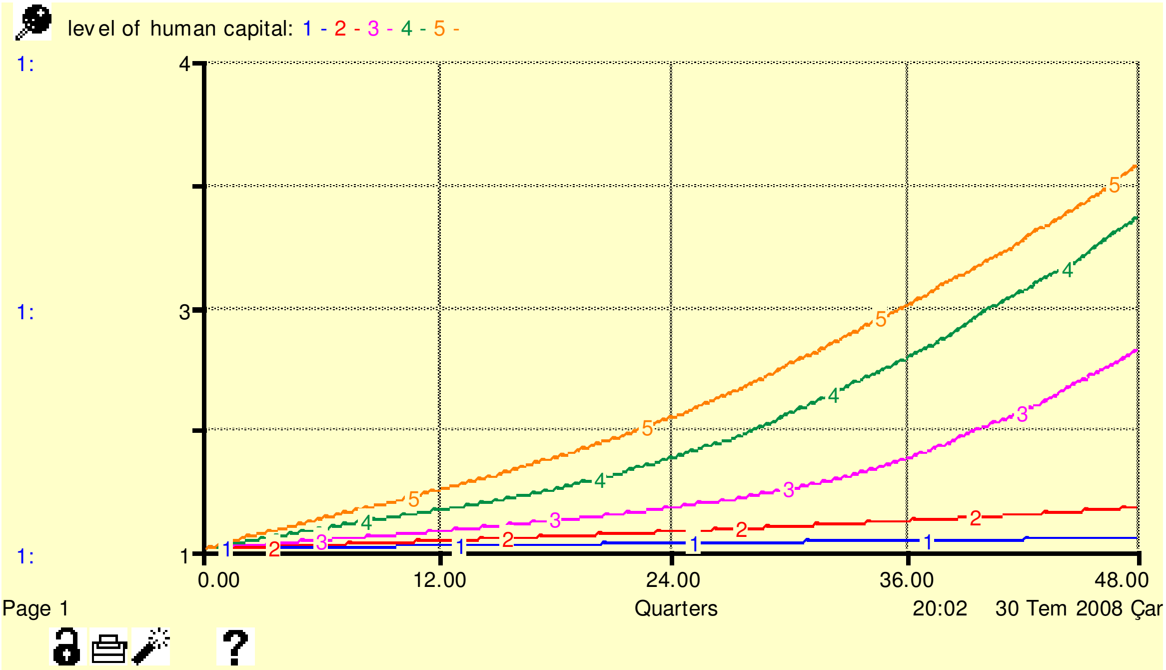

Figure 5.41 Human capital

The same pattern can be observed with the innovativeness pattern. When the initial level of the innovativeness is less than the reference level value, human capital also declines.

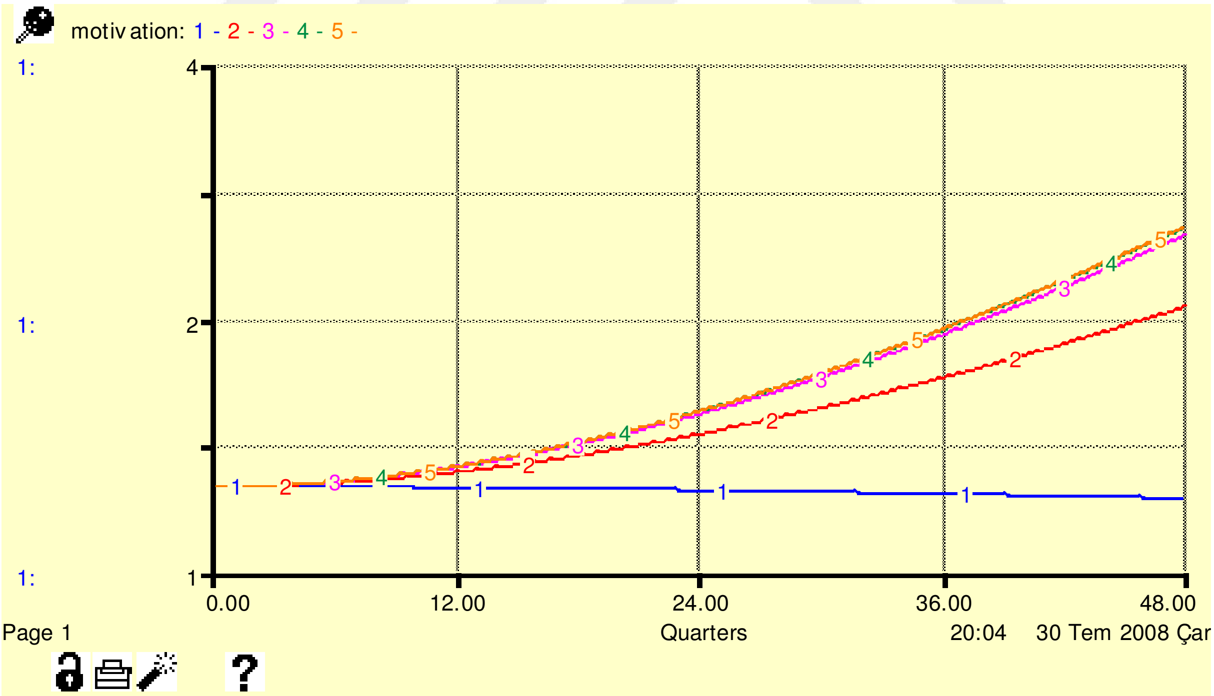

Figure 5.42 Motivation

Motivation shows the same pattern with the firm culture as it is expected.

5.3.4 Innovativeness decrease fraction changes between 0.01-0.1 with equal intervals for 10 runs.

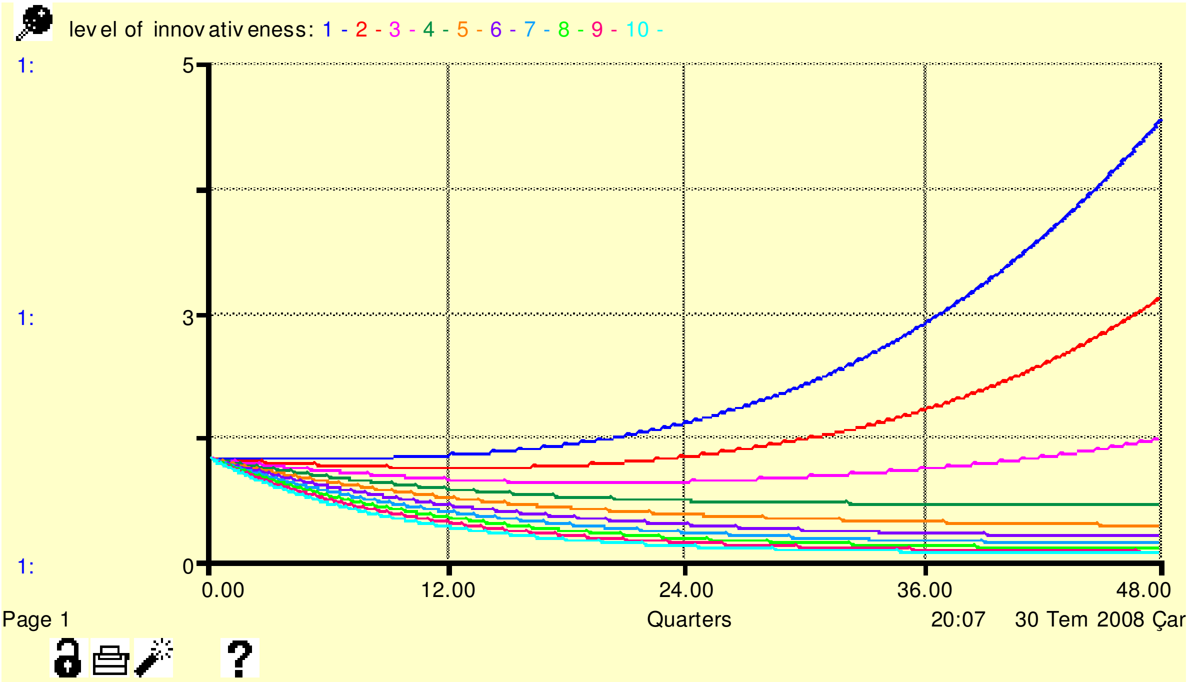

Figure 5.43 Level of innovativeness

Innovativeness decrease when the decrease fraction is lower than 0.03. Innovativeness decrease fraction is a critical variable. If there is a better innovative environment innovativeness decreases.

Table 5.15 Level of innovativeness

Innovativeness

17:35 08/08/2008 Table 1 (Innovativeness)

Quarters	1: level of inn	2: level of inn	3: level of inn	4: level of inn	5: level of inn
.0	1.00	1.00	1.00	1.00	1.00
4.0	0.96	0.88	0.81	0.74	0.67
8.0	0.94	0.78	0.66	0.55	0.46
12.0	0.93	0.71	0.54	0.41	0.32
16.0	0.94	0.66	0.46	0.32	0.23
20.0	0.98	0.62	0.39	0.25	0.17
24.0	1.06	0.60	0.35	0.21	0.13
28.0	1.18	0.59	0.31	0.17	0.10
32.0	1.35	0.58	0.28	0.15	0.08
36.0	1.57	0.57	0.26	0.13	0.07
40.0	1.89	0.57	0.24	0.12	0.06
44.0	2.29	0.58	0.23	0.11	0.06
Final	2.81	0.58	0.22	0.10	0.05

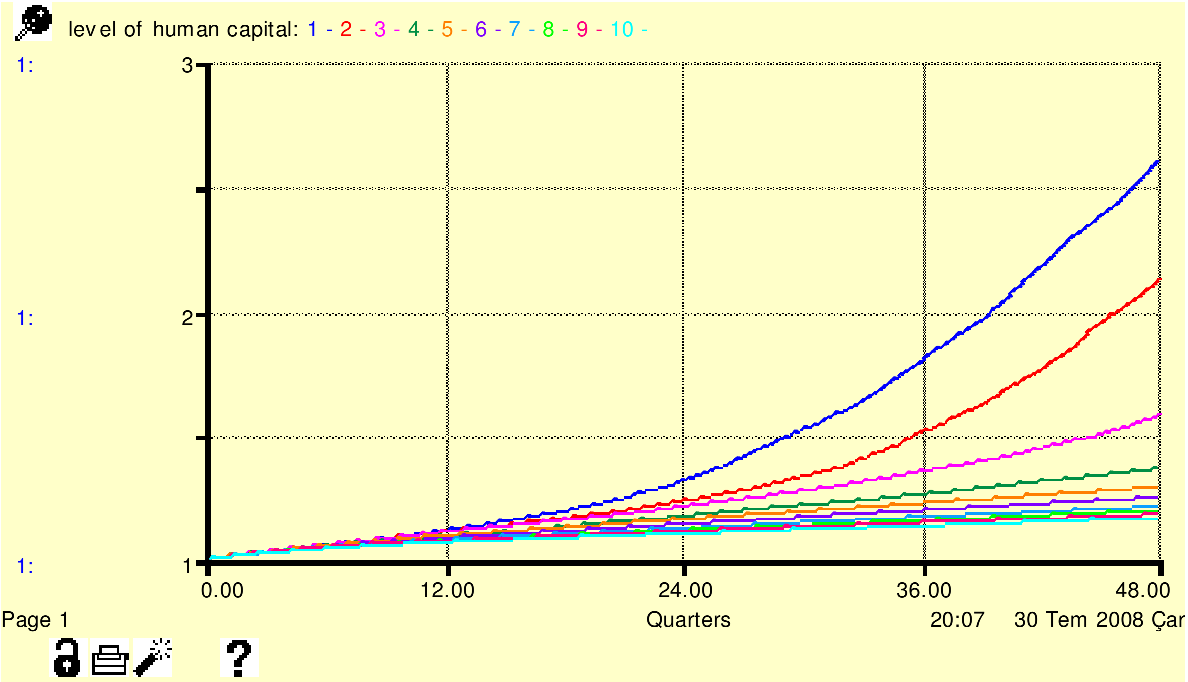

Figure 5.44 Human capital

It is observed that decrease fraction of the innovativeness should not be higher than 0.03.

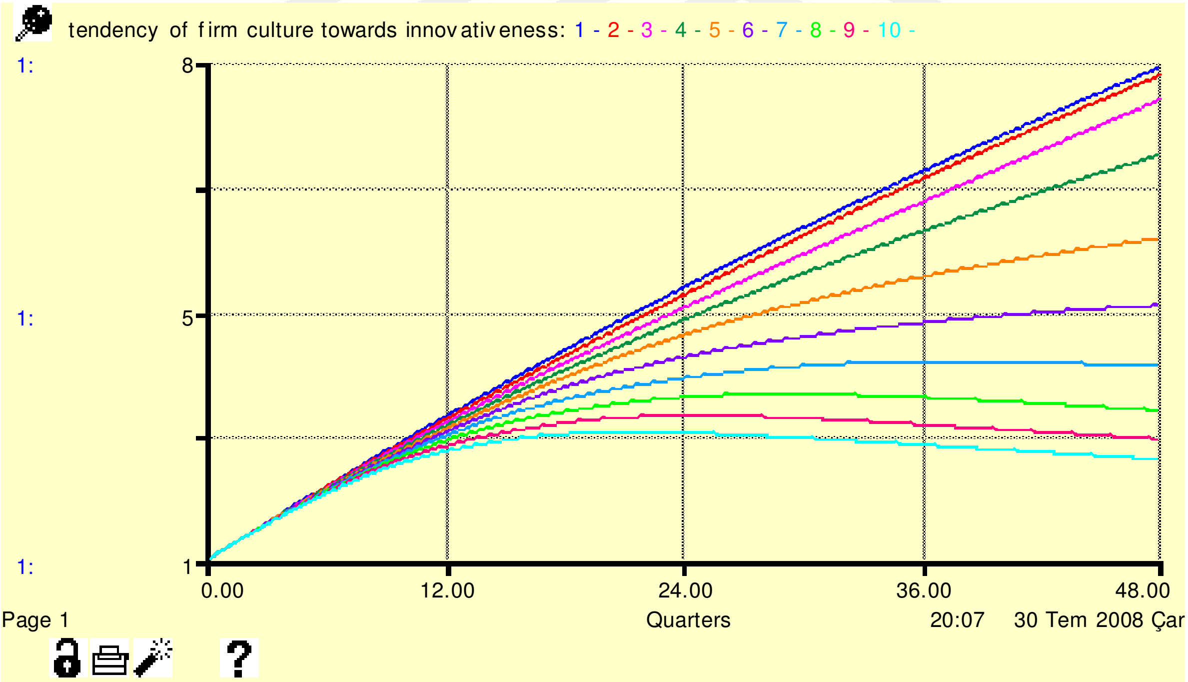

Figure 5.45 Firm culture

Table 5.16 Firm culture

Firm culture

17:35 08/08/2008 Table 2 (Firm culture)

Quarters	1: tendency	2: tendency	3: tendency	4: tendency	5: tendency
.0	1.00	1.00	1.00	1.00	1.00
4.0	1.69	1.68	1.67	1.66	1.65
8.0	2.35	2.31	2.27	2.23	2.18
12.0	2.98	2.89	2.80	2.68	2.52
16.0	3.58	3.42	3.25	2.98	2.72
20.0	4.17	3.92	3.60	3.17	2.79
24.0	4.75	4.39	3.87	3.29	2.79
28.0	5.31	4.83	4.07	3.34	2.74
32.0	5.85	5.26	4.24	3.33	2.68
36.0	6.38	5.66	4.37	3.30	2.61
40.0	6.88	6.05	4.47	3.24	2.54
44.0	7.37	6.42	4.56	3.18	2.47
Final	7.84	6.78	4.62	3.11	2.41

When the decrease fraction of the innovativeness changes between 0.01- 0.1 it is seen that firm culture also changes. Firm culture value changes significantly according to this parameter.

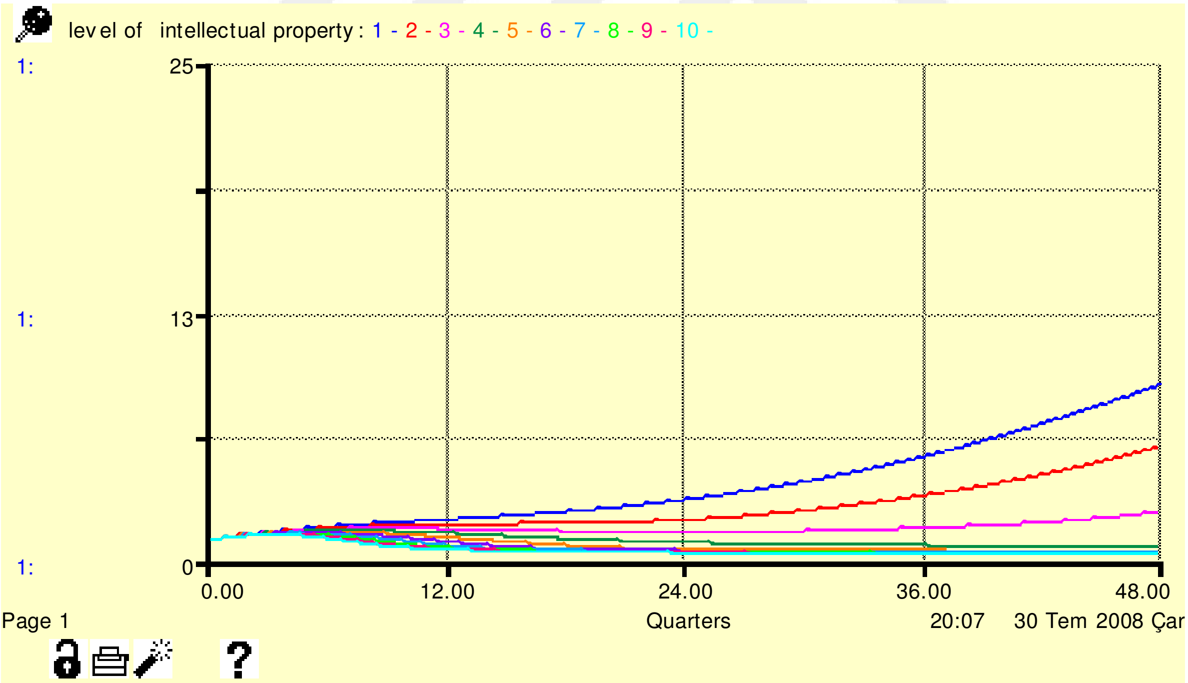

Figure 5.46 Level of intellectual property

Table 5.17 Intellectual property

Intellectual property

17:35 08/08/2008 Table 3 (Intellectual property)

Quarters	1: level of in	2: level of in	3: level of in	4: level of in	5: level of in
.0	1.00	1.00	1.00	1.00	1.00
4.0	1.48	1.43	1.37	1.31	1.24
8.0	1.71	1.50	1.27	1.02	0.78
12.0	1.81	1.37	0.93	0.62	0.52
16.0	1.86	1.19	0.62	0.49	0.43
20.0	1.94	1.03	0.53	0.44	0.39
24.0	2.09	0.92	0.49	0.41	0.36
28.0	2.41	0.85	0.46	0.38	0.35
32.0	2.86	0.81	0.44	0.37	0.33
36.0	3.44	0.79	0.43	0.36	0.33
40.0	4.14	0.78	0.42	0.35	0.32
44.0	5.01	0.78	0.41	0.35	0.32
Final	6.05	0.78	0.41	0.34	0.32

Level of IP can not increase if the decrease fraction is higher than 0.01. Innovativeness affects R&D efficiency and this affects the level of intellectual property.

5.3.5 Intellectual property initial value changes between 0-2 with equal intervals for 5 runs.

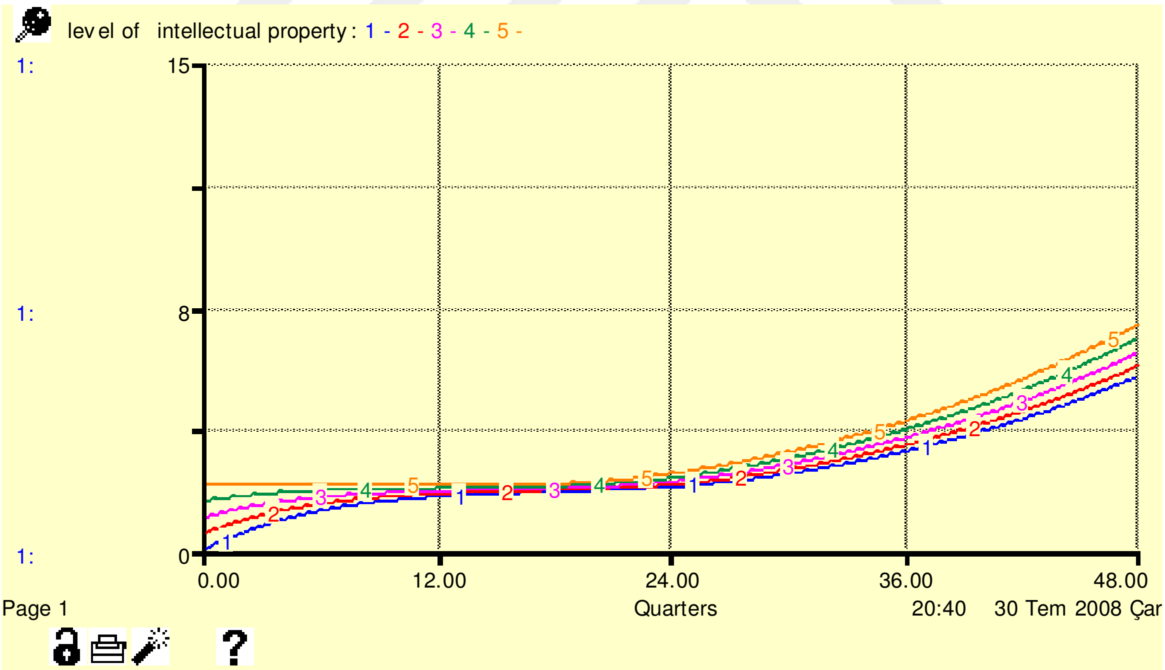

Figure 5.47 Level of intellectual property

In this case it is seen that the importance of the initial level of IP shows its significance after 6 years. There is no important effect between three and six years.

Table 5.18 Intellectual property

Intellectual property

17:35 07/08/2008 Table 1 (Intellectual property)

Quarters	1: level of int	2: level of int	3: level of int	4: level of int	5: level of int
.0	0.00	0.50	1.00	1.50	2.00
4.0	0.92	1.20	1.48	1.76	2.04
8.0	1.40	1.55	1.71	1.87	2.02
12.0	1.63	1.72	1.81	1.90	1.99
16.0	1.75	1.80	1.86	1.93	2.00
20.0	1.83	1.88	1.94	2.00	2.09
24.0	1.93	2.00	2.09	2.21	2.34
28.0	2.15	2.27	2.41	2.57	2.75
32.0	2.52	2.68	2.86	3.06	3.29
36.0	3.01	3.21	3.44	3.68	3.96
40.0	3.62	3.86	4.14	4.44	4.77
44.0	4.37	4.66	5.00	5.36	5.77
Final	5.30	5.64	6.04	6.46	6.92

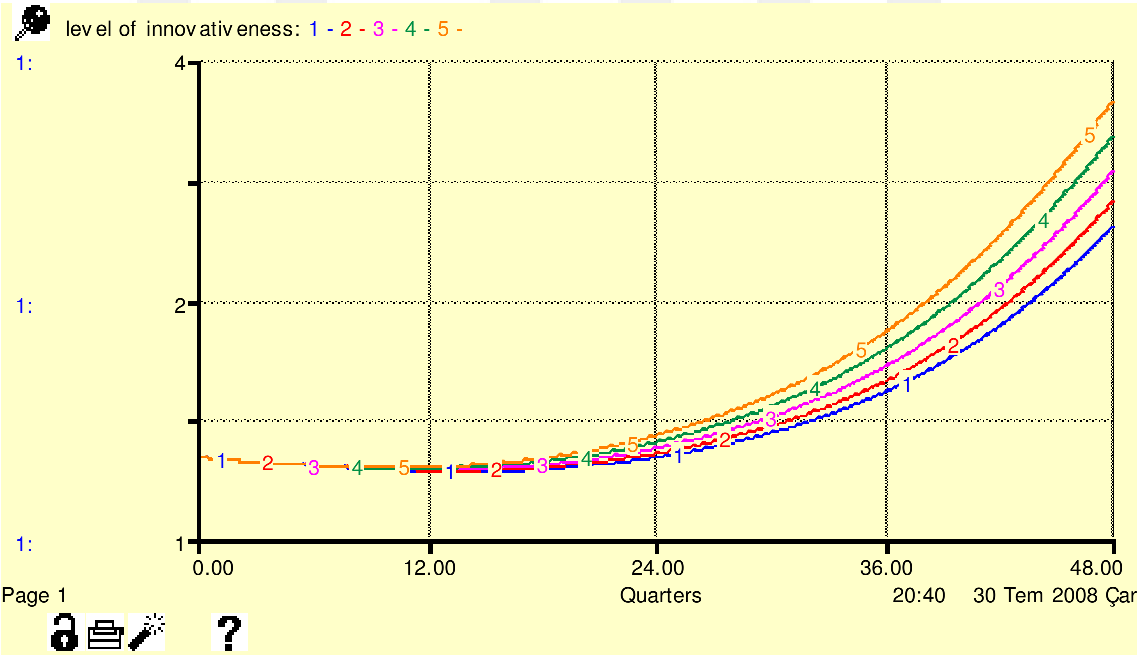

Figure 5.48 Level of innovativeness

Initial level of IP affects innovativeness after 3 years. Phase difference is observed.

5.3.6 Organizational capital initial value changes between 0-2 with equal intervals for 5 runs.

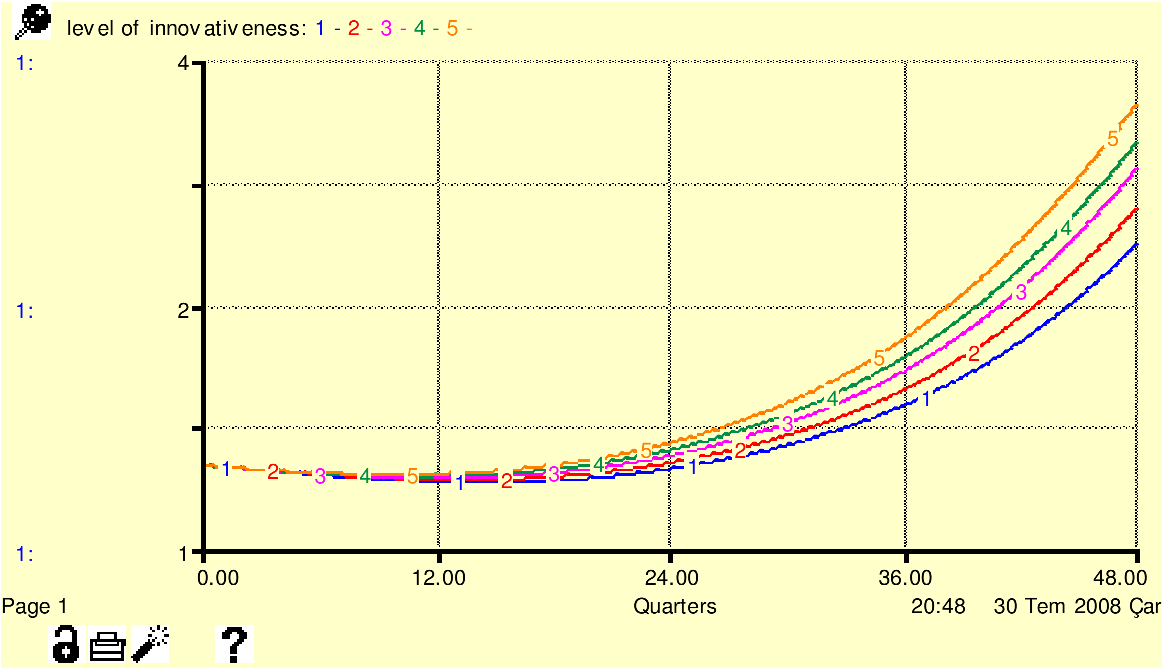

Figure 5.49 Level of innovativeness

Initial level organizational capital affects innovativeness in the same direction. Phase difference is same with the change in the initial level of IP.

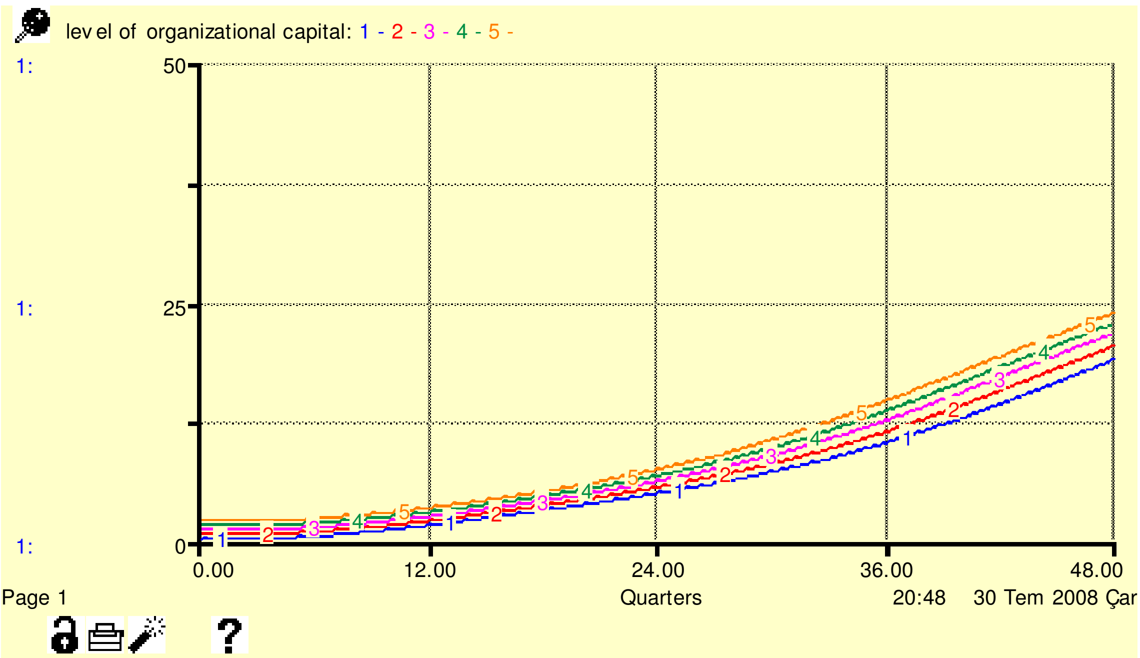

Figure 5.50 Level of organizational capital

Table 5.19 Organizational capital

Organizational capital

18:00 08/08/2008 Table 1 (Organizational capital)

Quarters	1: level of org	2: level of org	3: level of org	4: level of org	5: level of org
.0	0.00	0.50	1.00	1.50	2.00
4.0	0.14	0.62	1.10	1.58	2.06
8.0	0.66	1.12	1.59	2.05	2.52
12.0	1.50	1.96	2.42	2.87	3.33
16.0	2.51	2.99	3.46	3.94	4.42
20.0	3.62	4.15	4.68	5.20	5.73
24.0	4.83	5.46	6.10	6.72	7.33
28.0	6.25	7.04	7.79	8.51	9.25
32.0	7.98	8.93	9.85	10.74	11.63
36.0	10.08	11.28	12.38	13.41	14.43
40.0	12.67	14.06	15.31	16.44	17.53
44.0	15.64	17.15	18.44	19.57	20.63
Final	18.78	20.26	21.51	22.59	23.62

When the initial level of the organizational capital is higher, the value of the organizational capital is high as it is expected.

5.3.7 Human capital decrease fraction changes between 0.01-0.1 with equal intervals for 10 runs.

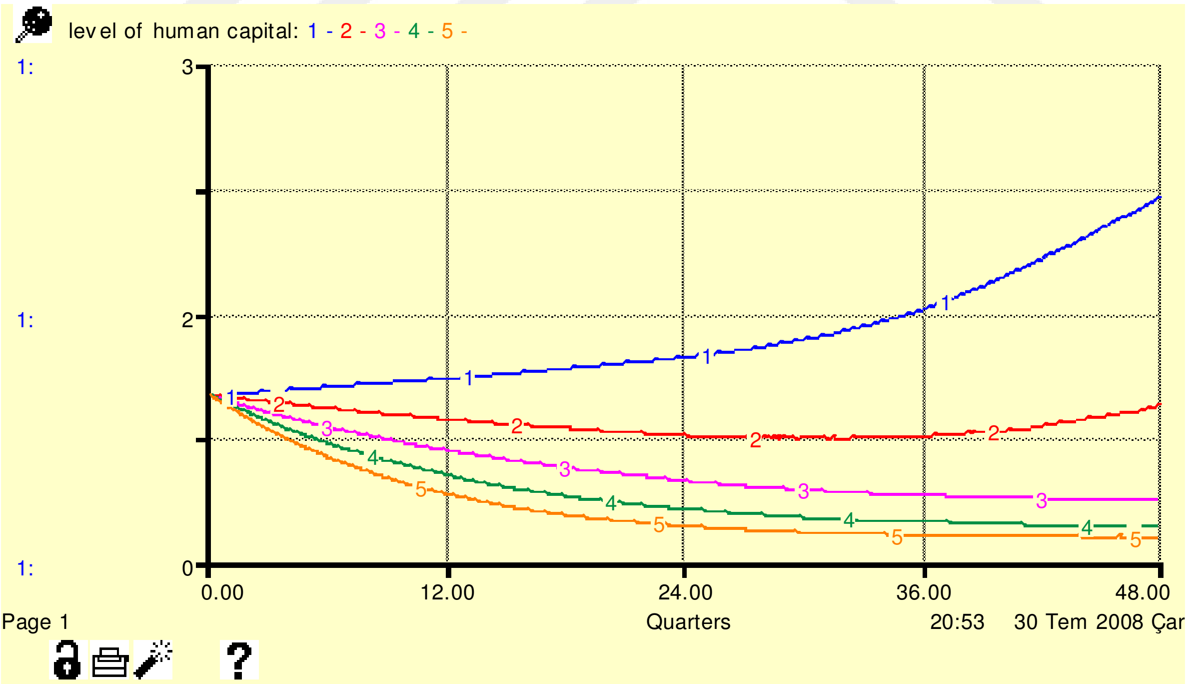

Figure 5.51 Level of human capital

Table 5.20 Human capital

Human capital

18:08 08/08/2008 Table 1 (Human capital)

Quarters	1: level of hu	2: level of hu	3: level of hu	4: level of hu	5: level of hu
.0	1.00	1.00	1.00	1.00	1.00
4.0	1.04	0.95	0.87	0.79	0.73
8.0	1.07	0.90	0.76	0.64	0.53
12.0	1.11	0.86	0.67	0.52	0.40
16.0	1.15	0.83	0.59	0.43	0.31
20.0	1.19	0.79	0.53	0.36	0.25
24.0	1.24	0.77	0.49	0.31	0.21
28.0	1.31	0.76	0.45	0.29	0.18
32.0	1.40	0.75	0.42	0.26	0.16
36.0	1.53	0.76	0.40	0.25	0.15
40.0	1.69	0.79	0.39	0.23	0.14
44.0	1.92	0.85	0.38	0.22	0.14
Final	2.17	0.94	0.37	0.22	0.15

Human capital can not increase if the decrease fraction of human capital is larger than 0.01.

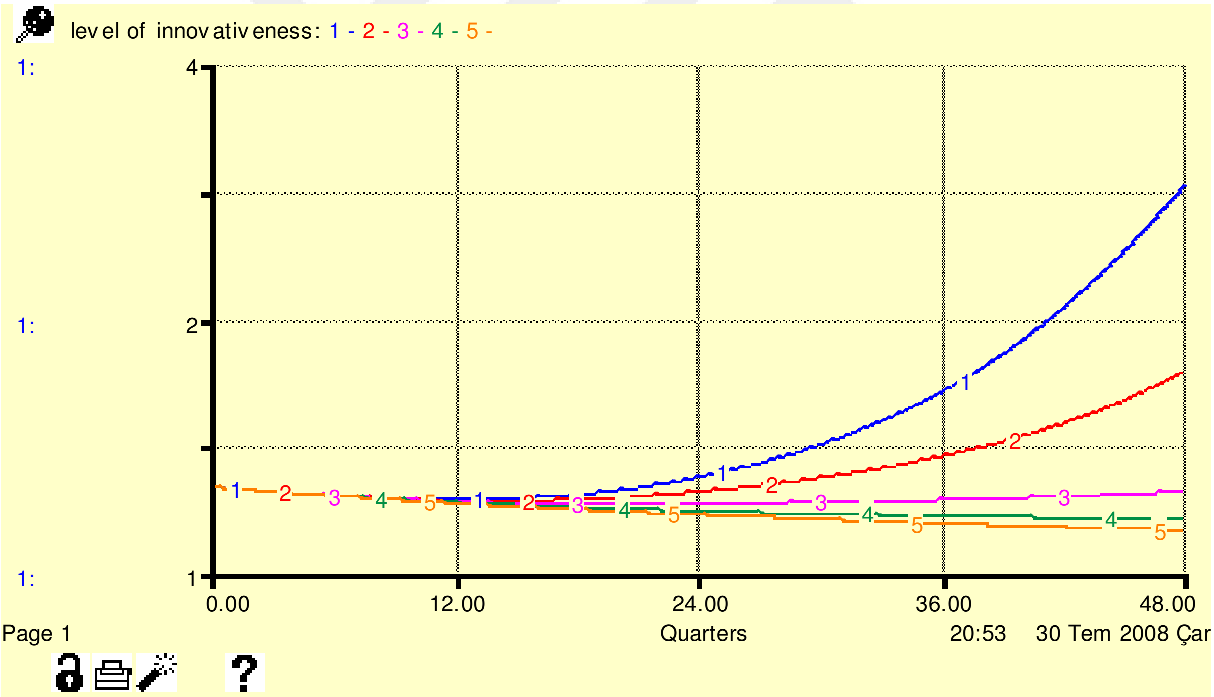

Figure 5.52 Level of innovativeness

Table 5.21 Level of innovativeness

Level of innovativeness

18:08 08/08/2008 Table 2 (Level of innovativeness)

Quarters	1: level of innov	2: level of innov	3: level of innov	4: level of innov	5: level of innov
.0	1.00	1.00	1.00	1.00	1.00
4.0	0.96	0.96	0.96	0.96	0.96
8.0	0.94	0.94	0.93	0.93	0.93
12.0	0.93	0.92	0.91	0.91	0.90
16.0	0.94	0.92	0.90	0.89	0.88
20.0	0.98	0.94	0.90	0.87	0.86
24.0	1.06	0.98	0.90	0.86	0.84
28.0	1.18	1.03	0.91	0.85	0.82
32.0	1.34	1.10	0.92	0.84	0.80
36.0	1.57	1.19	0.93	0.83	0.79
40.0	1.87	1.31	0.94	0.83	0.77
44.0	2.28	1.47	0.96	0.82	0.76
Final	2.79	1.69	0.98	0.82	0.74

Innovativeness can not increase if the decrease fraction of human capital is larger than 0.02.

5.3.8 Initial value of human capital changes between 0-2 with equal intervals for 5 runs.

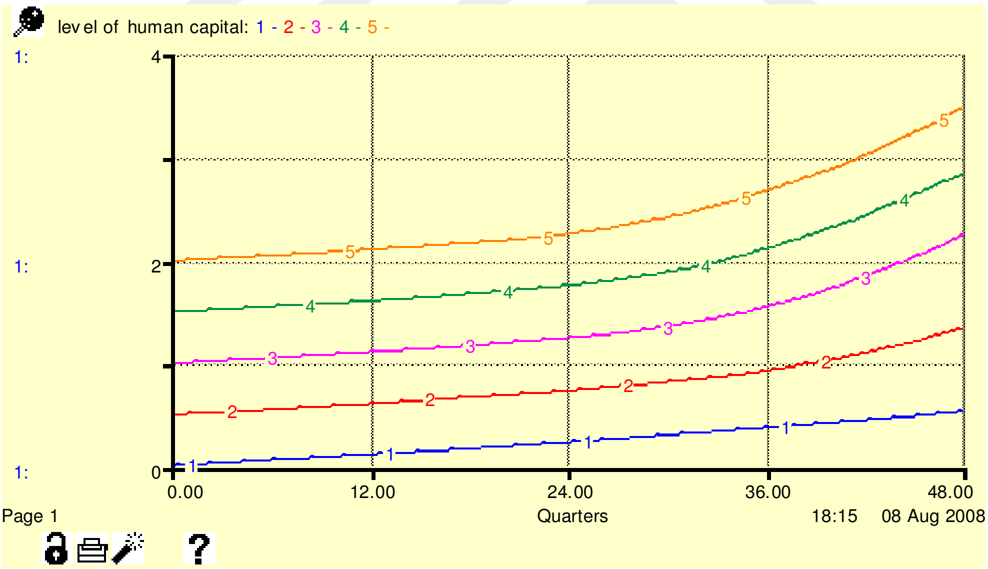

Figure 5.53 Human capital

Initial level of human capital affects human capital significantly.

Table 5.22 Human capital

Human capital

18:15 08/08/2008 Table 3 (Human capital)

Quarters	1: level of hu	2: level of hu	3: level of hu	4: level of hu	5: level of hu
.0	0.00	0.50	1.00	1.50	2.00
4.0	0.04	0.53	1.04	1.54	2.04
8.0	0.08	0.57	1.07	1.57	2.07
12.0	0.11	0.61	1.11	1.61	2.11
16.0	0.15	0.65	1.15	1.65	2.15
20.0	0.19	0.69	1.20	1.70	2.20
24.0	0.23	0.73	1.25	1.76	2.26
28.0	0.28	0.79	1.31	1.84	2.36
32.0	0.32	0.85	1.41	1.95	2.50
36.0	0.37	0.92	1.55	2.12	2.68
40.0	0.42	1.03	1.73	2.32	2.89
44.0	0.47	1.18	1.97	2.57	3.17
Final	0.53	1.34	2.25	2.83	3.48

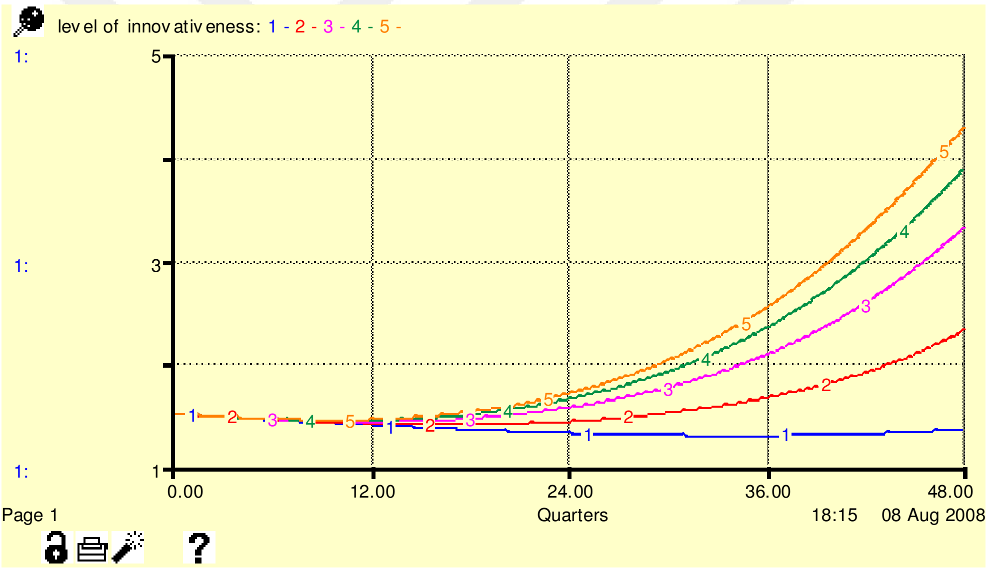

Figure 5.54 Level of innovativeness

Change in the initial value of human capital affects innovativeness after three years.

Table 5.23 Level of innovativeness

Level of innovativeness

18:15 08/08/2008 Table 4 (Level of innovativeness)

Quarters	1: level of inr	2: level of inr	3: level of inr	4: level of inr	5: level of inr
.0	1.00	1.00	1.00	1.00	1.00
4.0	0.96	0.96	0.96	0.97	0.97
8.0	0.92	0.93	0.94	0.94	0.95
12.0	0.89	0.91	0.93	0.94	0.95
16.0	0.86	0.89	0.94	0.97	0.98
20.0	0.83	0.90	0.98	1.03	1.06
24.0	0.81	0.93	1.06	1.14	1.20
28.0	0.80	0.97	1.18	1.31	1.39
32.0	0.79	1.05	1.34	1.53	1.66
36.0	0.79	1.15	1.57	1.83	2.03
40.0	0.80	1.30	1.88	2.24	2.50
44.0	0.82	1.51	2.29	2.75	3.09
Final	0.85	1.80	2.81	3.38	3.78

5.3.9 Initial value of motivation changes between 0-2 with equal intervals for 5 runs.

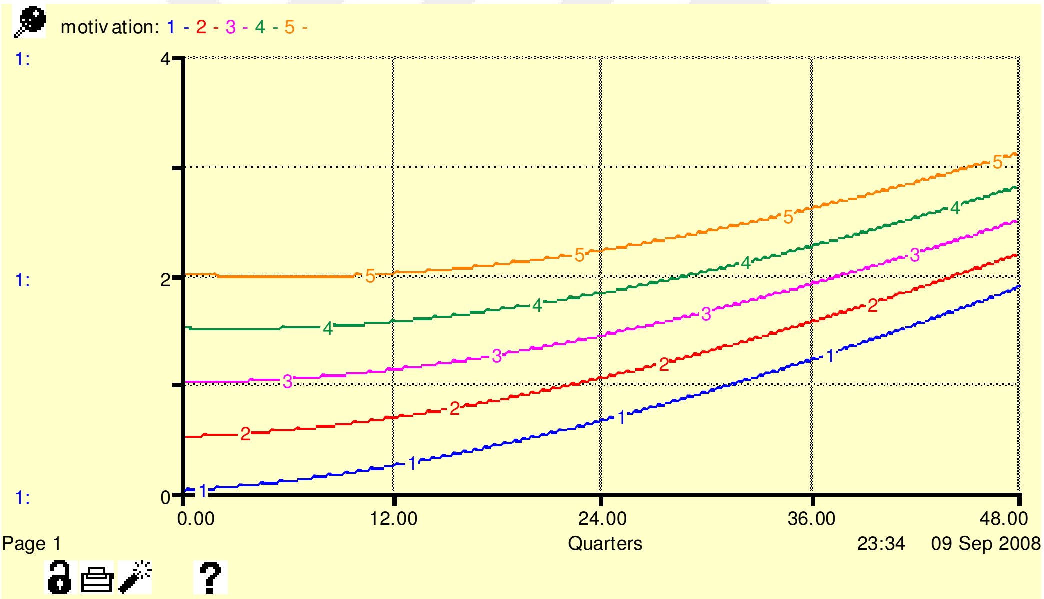

Figure 5.55 Motivation

When the initial value of motivation is 0, motivation level can increase up to a certain level.

Table 5.24 Motivation

Quarters	1: motivation	2: motivation	3: motivation	4: motivation	5: motivation
.0	0.00	0.50	1.00	1.50	2.00
4.0	0.05	0.53	1.01	1.49	1.97
8.0	0.13	0.59	1.05	1.51	1.98
12.0	0.23	0.67	1.12	1.56	2.00
16.0	0.35	0.77	1.20	1.63	2.05
20.0	0.49	0.90	1.31	1.72	2.12
24.0	0.64	1.04	1.43	1.82	2.22
28.0	0.81	1.19	1.57	1.95	2.33
32.0	1.00	1.36	1.73	2.09	2.45
36.0	1.20	1.55	1.90	2.25	2.60
40.0	1.41	1.75	2.08	2.42	2.76
44.0	1.64	1.96	2.28	2.61	2.93
Final	1.87	2.18	2.49	2.80	3.11

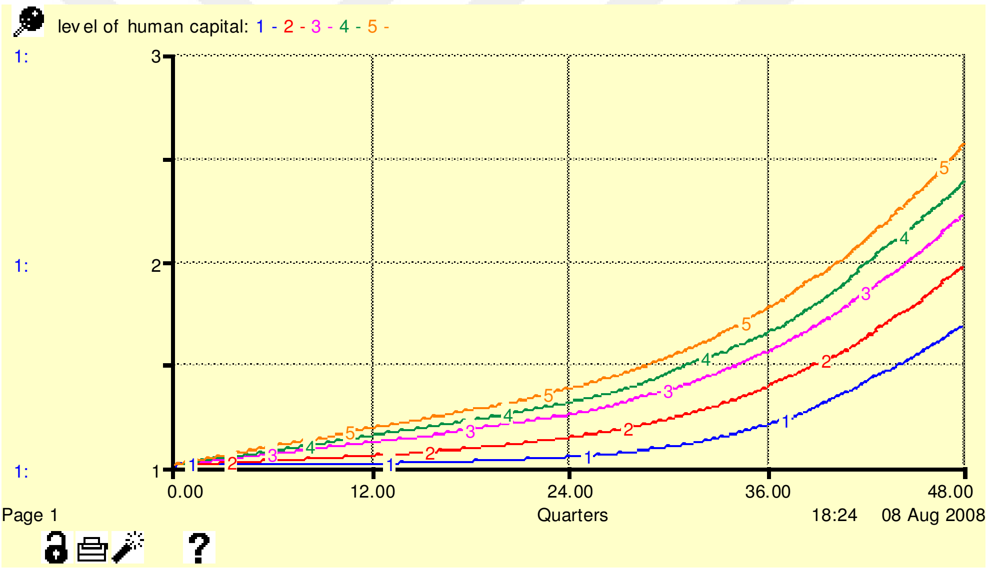

Figure 5.56 Level of human capital

Change in the motivation can be seen in the human capital in the short period.

Table 5.25 Human capital

Human capital

18:27 08/08/2008 Table 6 (Human capital)

Quarters	1: level of hu	2: level of hu	3: level of hu	4: level of hu	5: level of hu
.0	1.00	1.00	1.00	1.00	1.00
4.0	1.00	1.01	1.04	1.05	1.06
8.0	1.00	1.03	1.07	1.11	1.12
12.0	1.01	1.05	1.11	1.17	1.18
16.0	1.01	1.07	1.15	1.22	1.25
20.0	1.02	1.10	1.19	1.28	1.31
24.0	1.04	1.13	1.24	1.34	1.38
28.0	1.07	1.18	1.30	1.42	1.47
32.0	1.11	1.26	1.40	1.54	1.59
36.0	1.19	1.35	1.52	1.67	1.75
40.0	1.28	1.51	1.71	1.87	1.98
44.0	1.43	1.72	1.95	2.11	2.25
Final	1.65	1.98	2.23	2.37	2.55

It is seen that motivation level affects the level of human capital. Change can be seen quickly in the human capital.

5.3.10 Motivation decrease fraction changes between 0.01 and 0.1 with equal intervals for 5 runs.

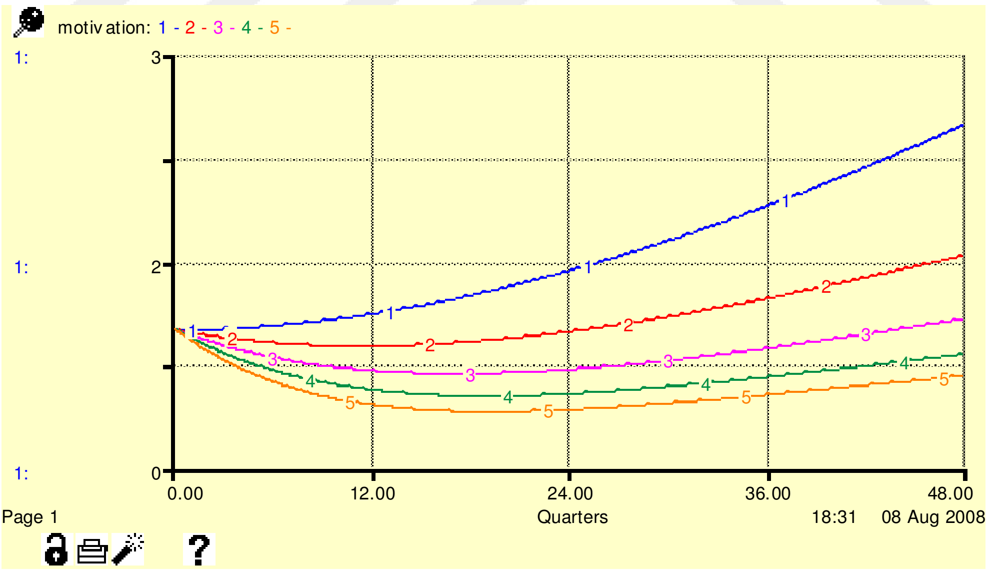

Figure 5.57 Motivation decrease fraction

It is seen that if the motivation decrease fraction is higher than 0.05 motivation decreases.

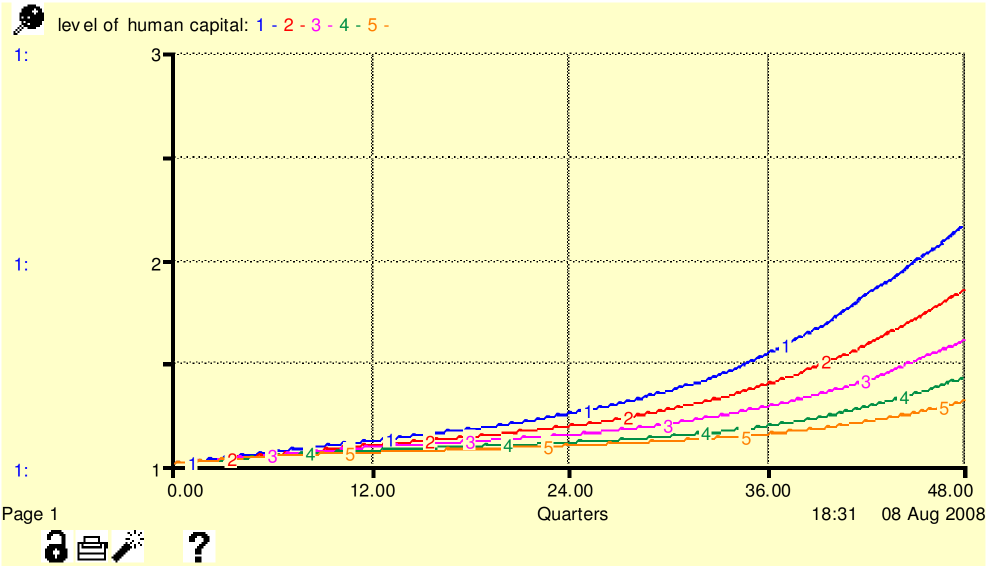

Figure 5.58 Human capital

As it is mentioned before, reference values were taken same with the initial values of the stocks which are 1.

5.3.11 Reference level of firm culture is changed between 1-5 with equal intervals for 5 runs.

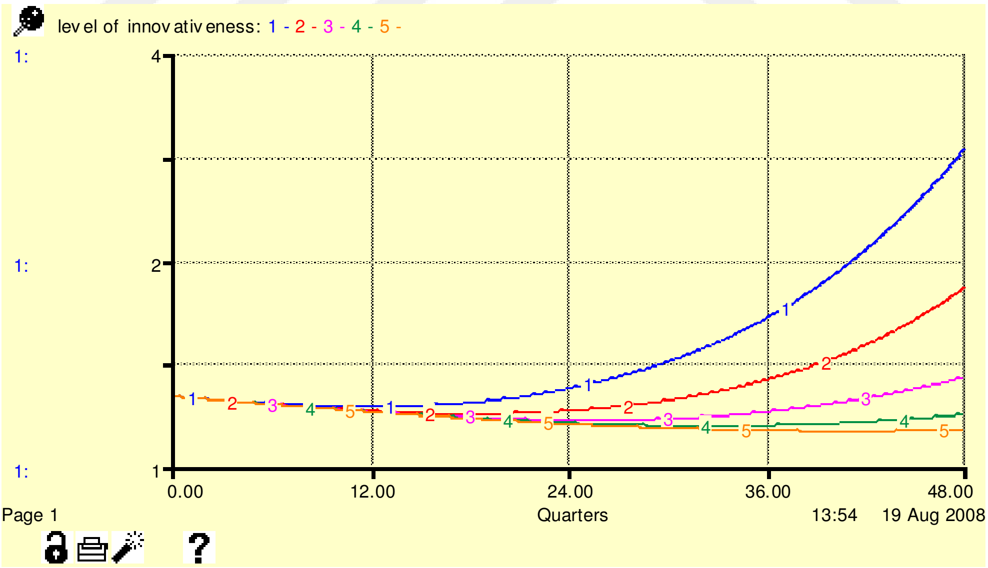

Figure 5.59 Level of innovativeness

Table 5.26 Innovativeness with reference values change

Innovativeness — 13:54 19/08/2008 — Table 5 (Innovativeness)

Quarters	1: level of inn	2: level of inn	3: level of inn	4: level of inn	5: level of inn
.0	1.00	1.00	1.00	1.00	1.00
4.0	0.96	0.96	0.96	0.96	0.96
8.0	0.94	0.93	0.92	0.92	0.92
12.0	0.93	0.90	0.89	0.89	0.89
16.0	0.94	0.88	0.86	0.86	0.86
20.0	0.98	0.88	0.84	0.83	0.83
24.0	1.06	0.90	0.83	0.81	0.80
28.0	1.18	0.94	0.83	0.79	0.78
32.0	1.34	1.01	0.85	0.79	0.76
36.0	1.57	1.12	0.89	0.79	0.75
40.0	1.88	1.27	0.95	0.80	0.75
44.0	2.28	1.49	1.03	0.83	0.75
Final	2.79	1.79	1.14	0.87	0.76

When the reference level value of firm culture is higher than initial value of firm culture, firstly innovativeness decreases until 20th quarter, but then it starts to increase. Moreover, if the reference value of firm culture is 4 times larger than the initial value of the stock, innovativeness can not increase. As a result, in order to be innovative in the long run there should not be significant difference with the competitor.

5.3.12 Reference level of human capital is changed between 1-5 with equal intervals for 5 runs.

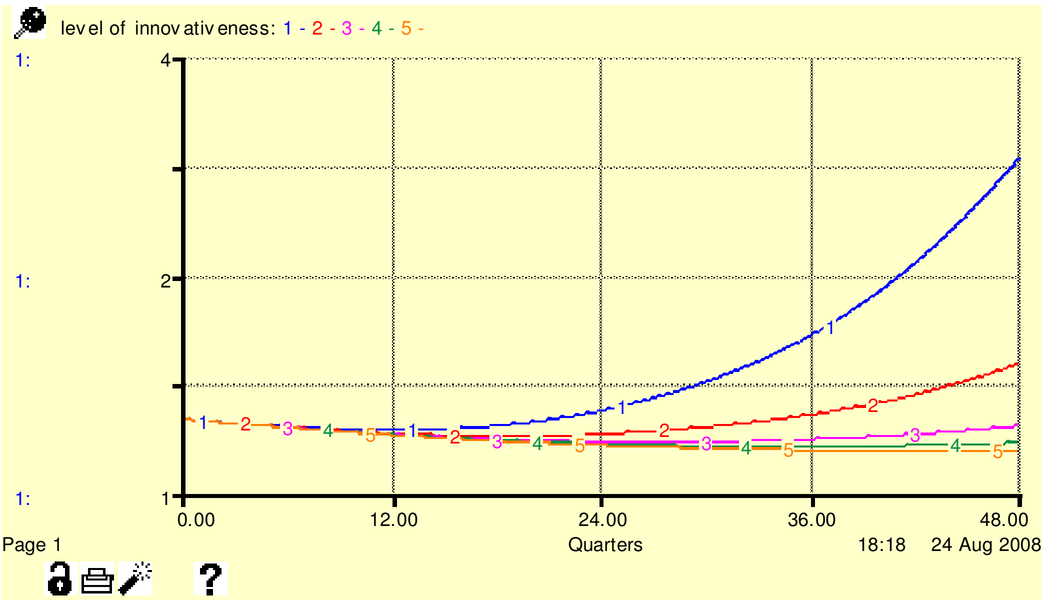

Figure 5.60 Level of innovativeness

5.3.13 Reference level of organizational capital is changed between 1-5 with equal intervals for 5 runs.

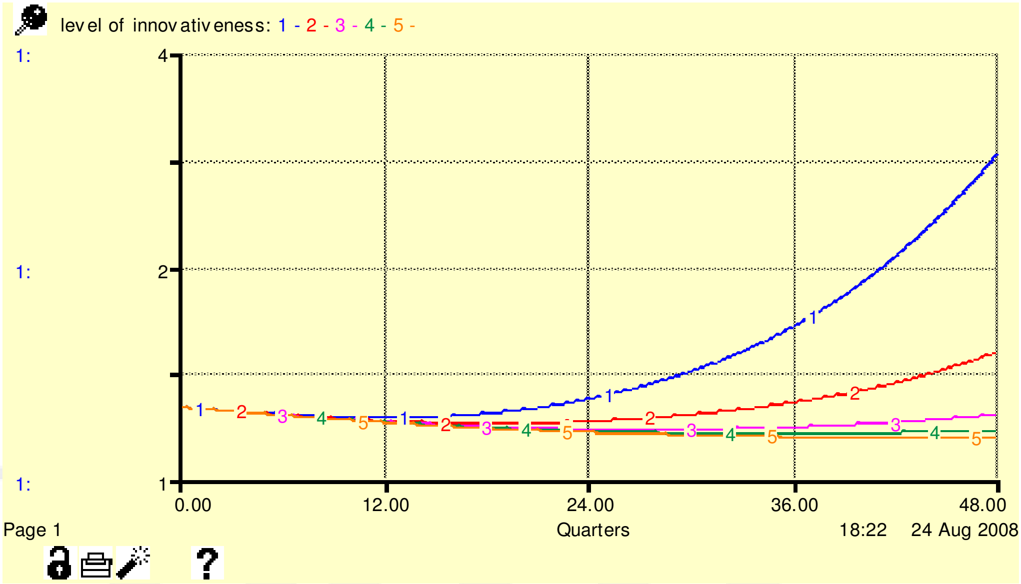

Figure 5.61 Level of innovativeness

When reference level of human capital and organizational capital are changed, it is seen that innovativeness changes in the same pattern.

5.3.14 Reference level is changed between 10-50 with equal intervals for 5 runs.

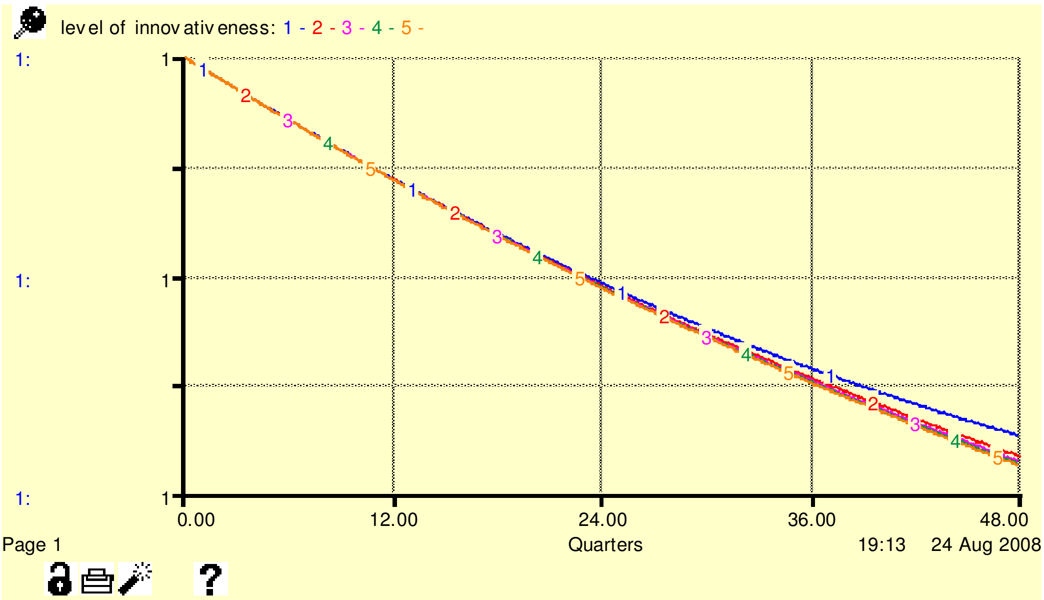

Figure 5.62 Level of innovativeness

Innovativeness decreases for the large values of reference level of firm culture.

5.3.15 Reference level of human capital and firm culture are changed between 1-5 with equal intervals for 5 runs.

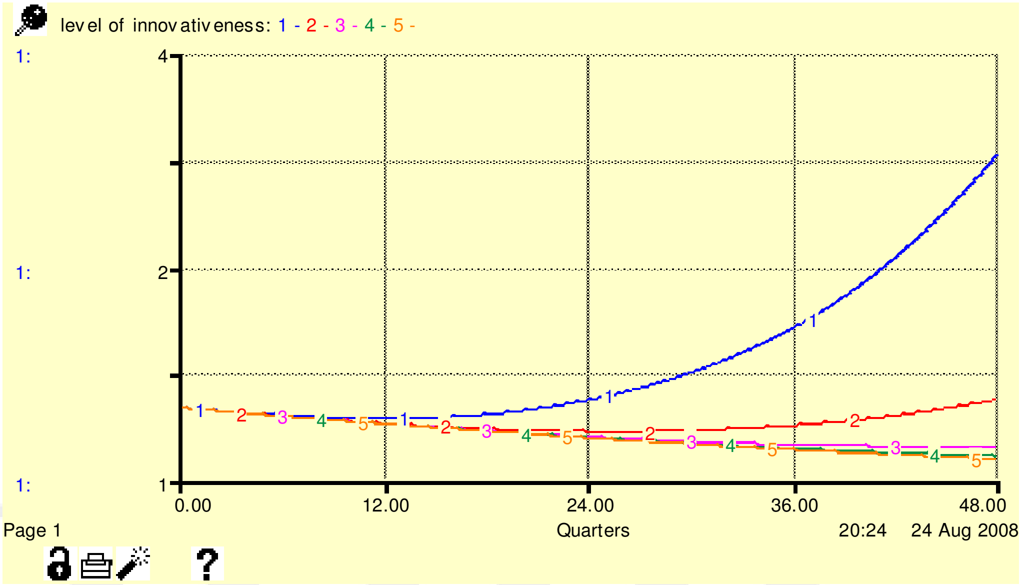

Figure 5.63 Level of innovativeness

Table 5.27 Innovativeness values

extreme values

20:24 24/08/2008 Table 9 (extreme values)

Quarters	1: level of inn	2: level of inn	3: level of inn	4: level of inn	5: level of inn
4.0	0.96	0.96	0.96	0.96	0.96
8.0	0.94	0.92	0.92	0.92	0.92
12.0	0.93	0.89	0.89	0.89	0.89
16.0	0.94	0.86	0.85	0.85	0.85
20.0	0.98	0.84	0.82	0.82	0.82
24.0	1.06	0.84	0.80	0.79	0.79
28.0	1.17	0.84	0.77	0.76	0.76
32.0	1.34	0.85	0.75	0.74	0.73
36.0	1.56	0.88	0.74	0.71	0.71
40.0	1.87	0.92	0.73	0.69	0.68
44.0	2.27	0.98	0.73	0.68	0.66
Final	2.78	1.06	0.73	0.66	0.64

It is seen that if the reference level of human capital and firm culture are larger than 1 at the same time, innovativeness decreases significantly. In other words, the total negative effect of competitor can be seen well.

5.3.16 Reference level of human capital and organizational capital are changed between 1-5 with equal intervals for 5 runs.

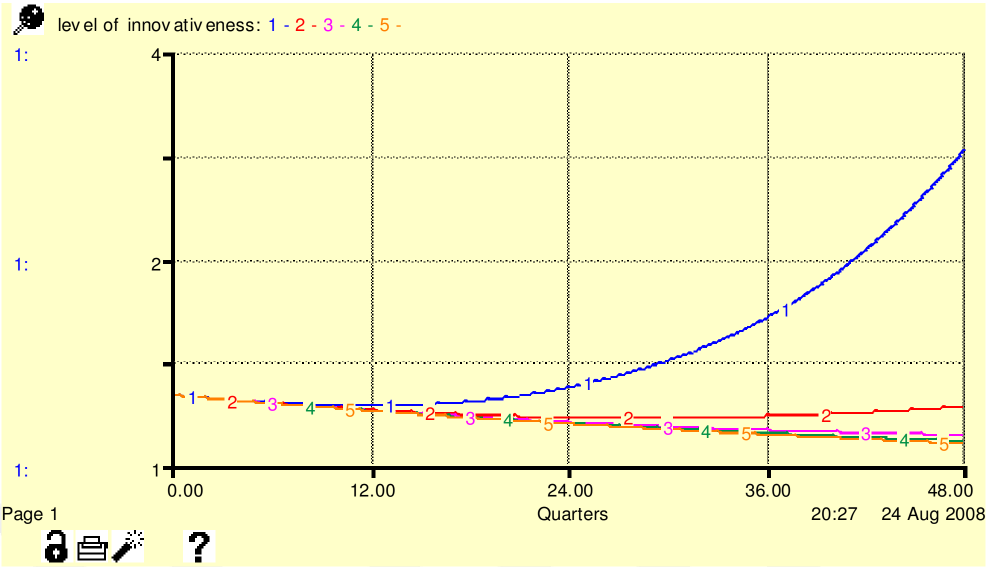

Figure 5.64 Level of innovativeness

Table 5.28 Innovativeness values

Untitled Table

20:27 24/08/2008 Table 10 (Untitled Table)

Quarters	1: level of inr	2: level of inr	3: level of inr	4: level of inr	5: level of inr
4.0	0.96	0.96	0.96	0.96	0.96
8.0	0.94	0.93	0.92	0.92	0.92
12.0	0.93	0.90	0.89	0.89	0.89
16.0	0.94	0.87	0.86	0.86	0.85
20.0	0.98	0.85	0.83	0.83	0.82
24.0	1.06	0.84	0.81	0.80	0.79
28.0	1.18	0.84	0.78	0.77	0.77
32.0	1.34	0.84	0.77	0.75	0.74
36.0	1.56	0.85	0.75	0.73	0.72
40.0	1.87	0.87	0.73	0.71	0.69
44.0	2.27	0.89	0.72	0.69	0.67
Final	2.78	0.92	0.71	0.67	0.65

In this case, when reference level of human capital and organizational capital are 2, innovativeness decreases more than the previous case.

5.3.17 Reference level of firm culture and organizational capital are changed between 1-5 with equal intervals for 5 runs.

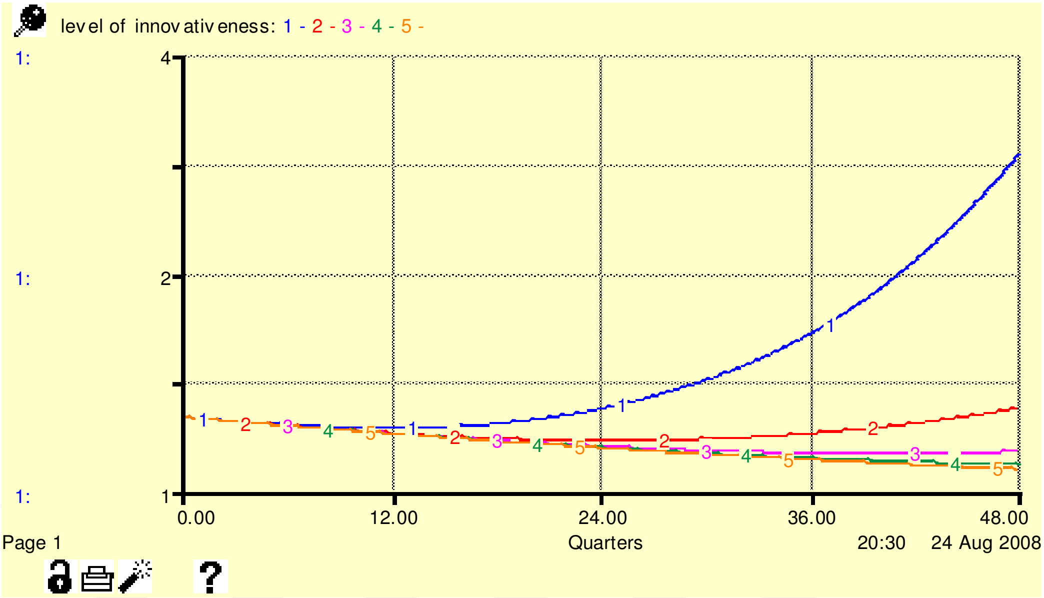

Figure 5.65 Level of innovativeness

Table 5.29 Innovativeness values

reference values

20:30 24/08/2008 Table 11 (reference values)

Quarters	1: level of inn	2: level of inn	3: level of inn	4: level of inn	5: level of inn
.0	1.00	1.00	1.00	1.00	1.00
4.0	0.96	0.96	0.96	0.96	0.96
8.0	0.94	0.92	0.92	0.92	0.92
12.0	0.93	0.89	0.89	0.89	0.89
16.0	0.94	0.86	0.86	0.85	0.85
20.0	0.98	0.85	0.83	0.82	0.82
24.0	1.06	0.84	0.80	0.79	0.79
28.0	1.18	0.85	0.78	0.77	0.76
32.0	1.35	0.86	0.77	0.74	0.73
36.0	1.57	0.89	0.76	0.72	0.71
40.0	1.88	0.93	0.76	0.70	0.68
44.0	2.29	0.99	0.76	0.69	0.66
Final	2.81	1.07	0.76	0.68	0.64

It is seen that innovativeness can not increase when the reference level values are 3.

5.3.18 Reference level of firm culture, human capital and organizational capital are changed between 1-5 with equal intervals for 5 runs.

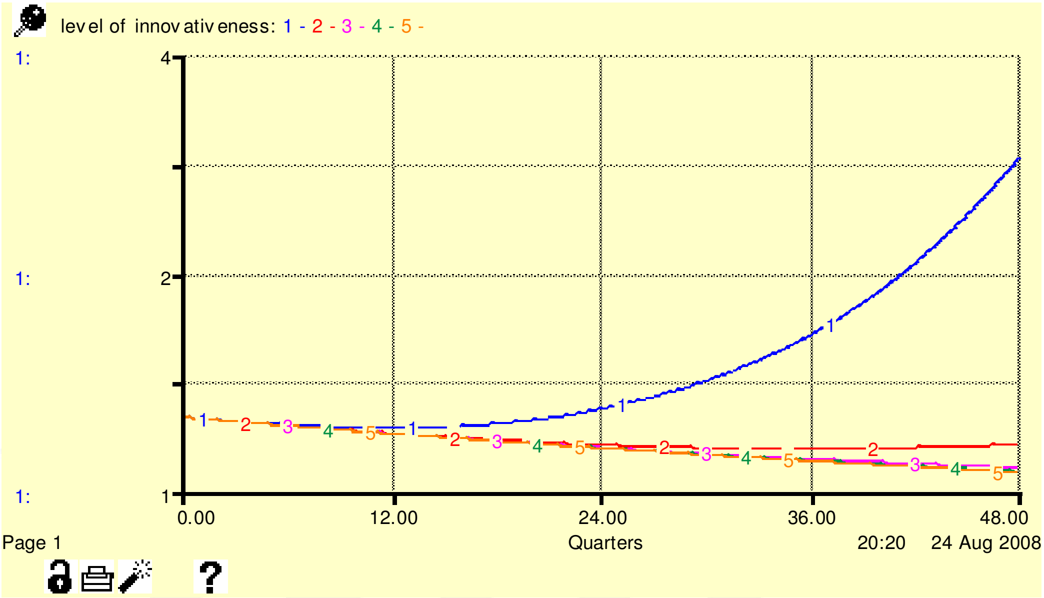

Figure 5.66 Level of innovativeness

Table 5.30 Innovativeness values

reference values

20:20 24/08/2008 Table 8 (reference values)

Quarters	1: level of inr	2: level of inr	3: level of inr	4: level of inr	5: level of inr
8.0	0.94	0.92	0.92	0.92	0.92
12.0	0.93	0.89	0.89	0.89	0.89
16.0	0.94	0.86	0.85	0.85	0.85
20.0	0.98	0.83	0.82	0.82	0.82
24.0	1.06	0.81	0.79	0.79	0.79
28.0	1.18	0.80	0.76	0.76	0.76
32.0	1.34	0.79	0.74	0.73	0.73
36.0	1.56	0.78	0.71	0.70	0.70
40.0	1.87	0.79	0.69	0.68	0.67
44.0	2.27	0.80	0.67	0.65	0.65
Final	2.79	0.81	0.66	0.63	0.62

Innovativeness decreases when values of reference level of human capital and organizational capital are 2.

Sensitivity analysis can also be applied to graphical functions. In the base run graphical functions are assumed as *S-Shaped* functions according to the TÜBİTAK Project (TÜBİTAK, 2007). A commonly observed behaviour in the dynamic system is *S-Shaped* growth. Growth is exponential first, but then it gradually slows.

5.3.19 The increase in the S curve is faster in this case. We assumed all the graphical functions as below.

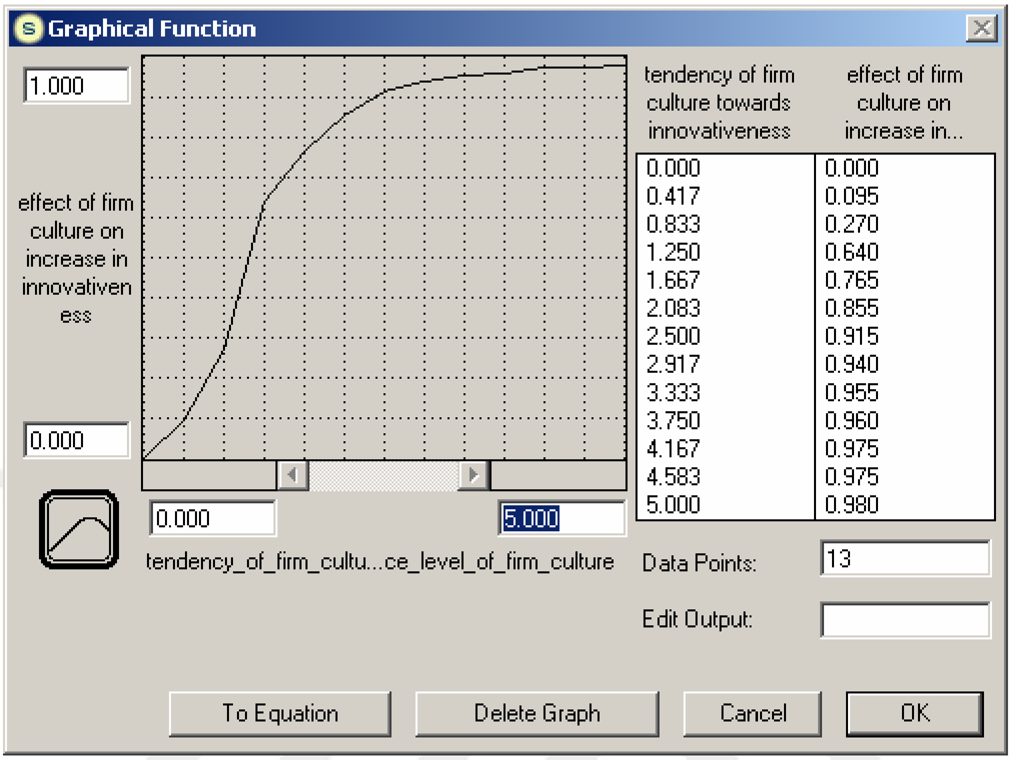

Figure 5.67 Effect of firm culture on innovativeness

In this case results are below.

Table 5.31 Base run with different effect formulation

Baserun with different effect formulation

19:33 08/08/2008 Table 10 (Baserun with different effect formulation)

Quarters	level of huma	level of innov	tendency of	motivation
.0	1.00	1.00	1.00	1.00
4.0	1.04	1.04	1.69	1.01
8.0	1.08	1.15	2.36	1.05
12.0	1.15	1.29	3.01	1.12
16.0	1.25	1.46	3.63	1.20
20.0	1.40	1.65	4.23	1.31
24.0	1.55	1.86	4.81	1.44
28.0	1.76	2.08	5.36	1.58
32.0	2.02	2.31	5.90	1.74
36.0	2.31	2.55	6.41	1.91
40.0	2.62	2.79	6.91	2.10
44.0	2.93	3.04	7.39	2.29
Final	3.27	3.28	7.85	2.50

Table 5.32 Base run of organizational capital elements

Base run with different effect formulation

19:33 08/08/2008 Table 11 (Base run with different effect formulation)

Quarters	level of intellectual propert	total infrastructure possess	level of organizational capit
.0	1.00	1.00	1.00
4.0	1.53	1.86	2.62
8.0	2.00	2.53	5.19
12.0	2.51	3.06	8.19
16.0	3.08	3.47	11.34
20.0	3.71	3.80	14.49
24.0	4.40	4.06	17.60
28.0	5.15	4.26	20.64
32.0	5.99	4.42	23.58
36.0	6.90	4.54	26.40
40.0	7.88	4.64	29.12
44.0	8.90	4.72	31.73
Final	9.96	4.78	34.25

When it is compared with the previous *S-Shaped* curves, it is seen that in this case stock values increase. In the previous case innovativeness value was 2.80. In this case it is 3.27. It is observed that there is no significant change when the S-shaped curves are changed. If we take all graphical functions linear, it is seen that all the stock values become extremely larger which is not sensible.

5.3.20 Half life of intellectual property graphical function is changed. In this case increase in the half life changes as given below.

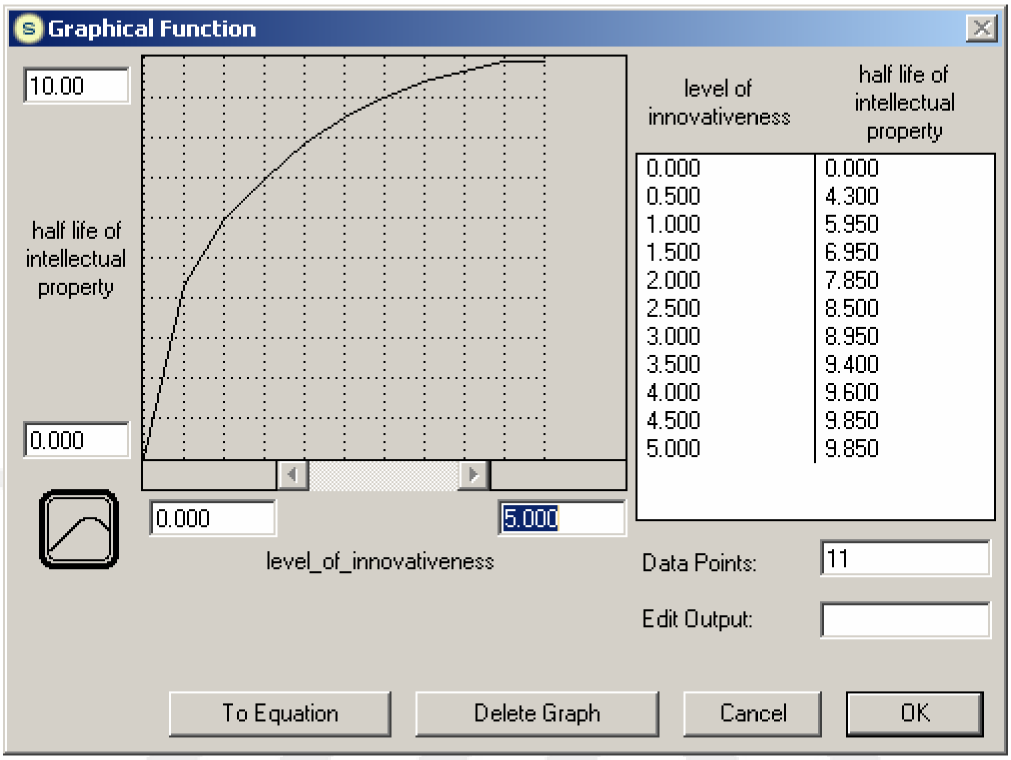

Figure 5.68 Half life graphical function

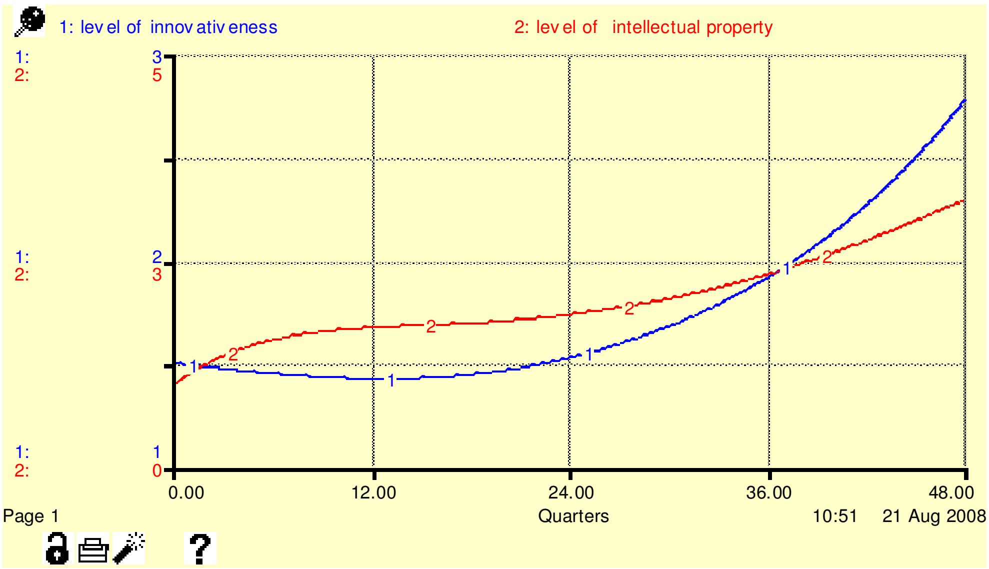

Figure 5.69 Innovativeness and intellectual property

Table 5.33 Stock values of innovativeness and intellectual property

Half-Life

10:52 21/08/2008 Table 2 (Half-Life)

Quarters	level of innov	level of intel
.0	1.00	1.00
4.0	0.96	1.58
8.0	0.94	1.92
12.0	0.93	2.12
16.0	0.96	2.25
20.0	1.02	2.37
24.0	1.13	2.48
28.0	1.29	2.62
32.0	1.51	2.78
36.0	1.79	3.00
40.0	2.14	3.27
44.0	2.58	3.57
Final	3.12	3.90

It is seen that IP reaches a larger value if there is an immediate increase on half life.

5.3.21 Half life of graphical function is changed.

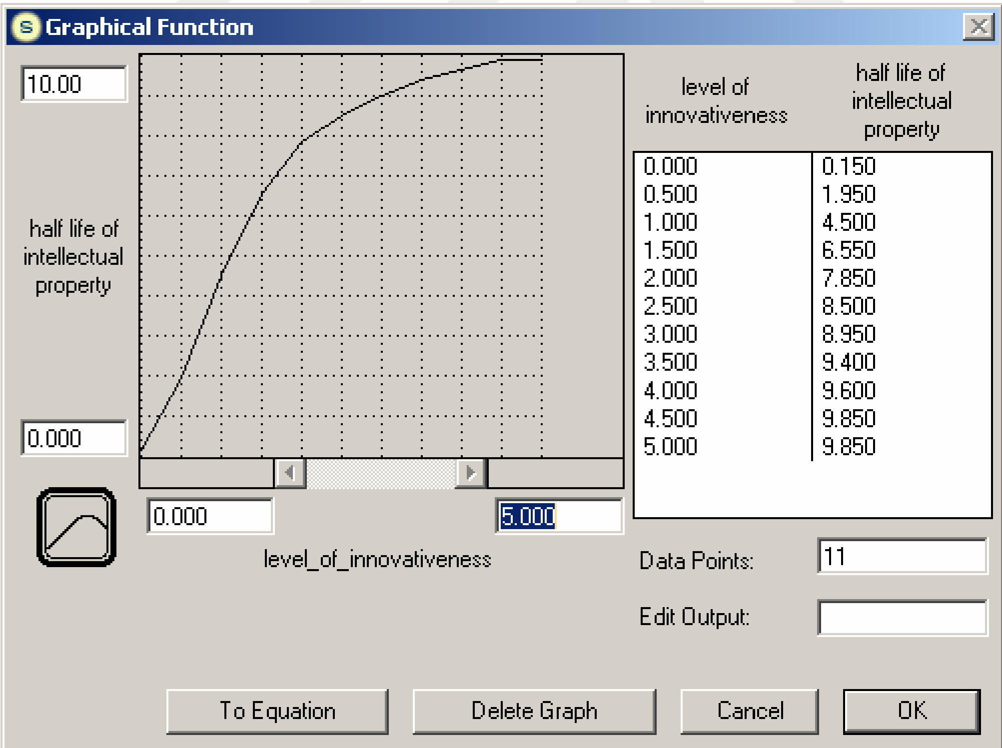

Figure 5.70 Half life graphical function

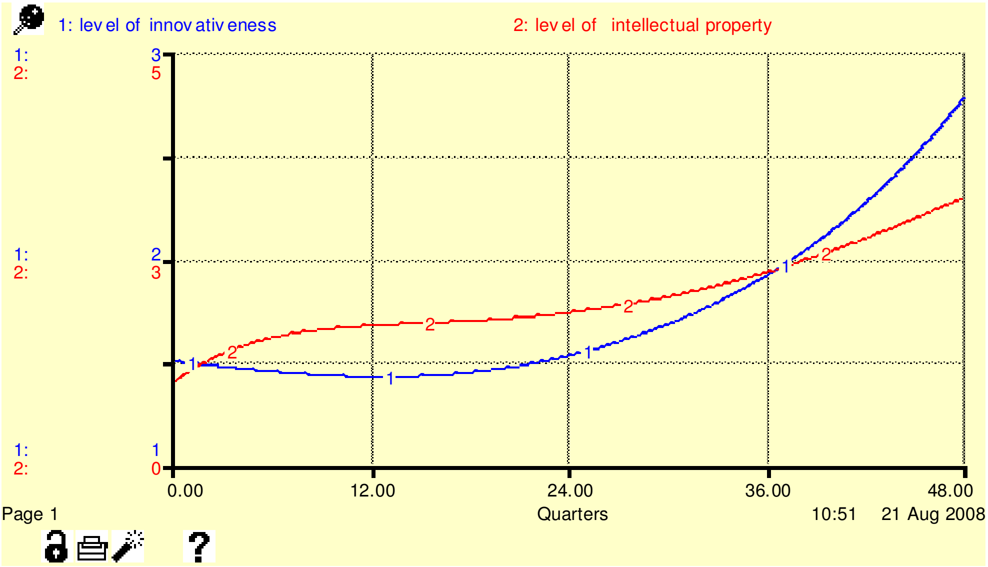

Figure 5.71 Innovativeness and intellectual property

When the increase is slow, it is seen that levels of IP and innovativeness have smaller values than the previous case.

Table 5.34 Stock values of innovation and intellectual property

Untitled Table

10:51 21/08/2008 Table 2 (Untitled Table)

Quarters	level of innov	level of intel
4.0	0.96	1.42
8.0	0.94	1.61
12.0	0.92	1.69
16.0	0.93	1.72
20.0	0.97	1.77
24.0	1.03	1.85
28.0	1.12	1.96
32.0	1.25	2.12
36.0	1.41	2.33
40.0	1.63	2.59
44.0	1.91	2.90
Final	2.27	3.24

5.3.22 Half life of graphical function is changed.

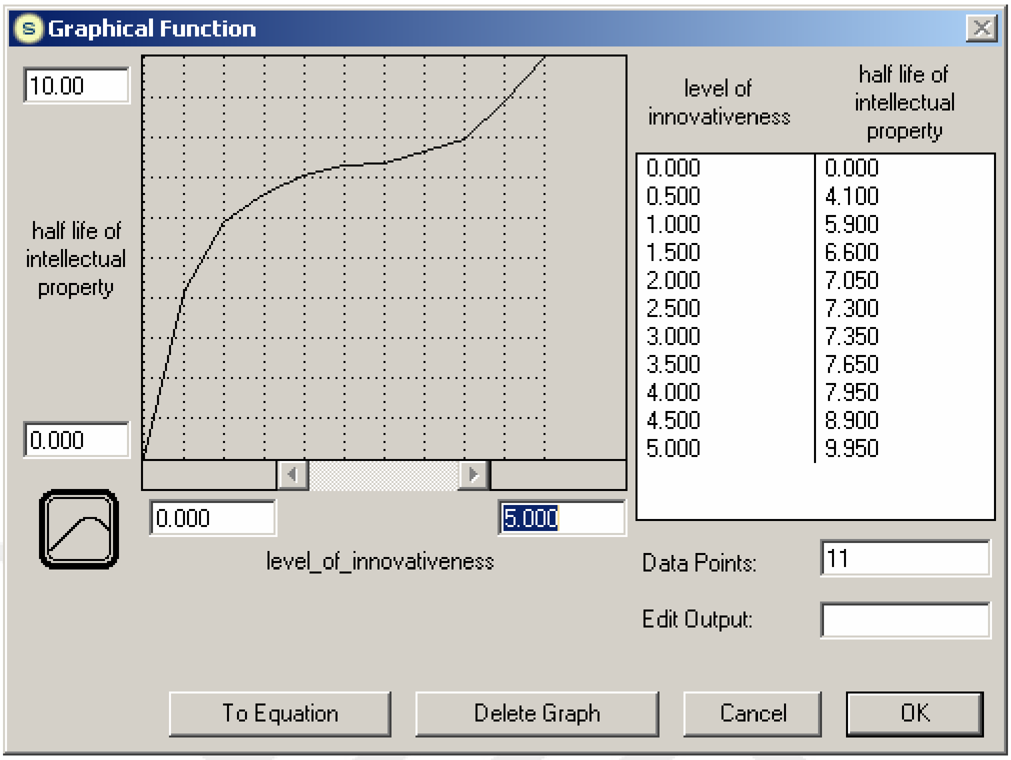

Figure 5.72 Half-life graphical function

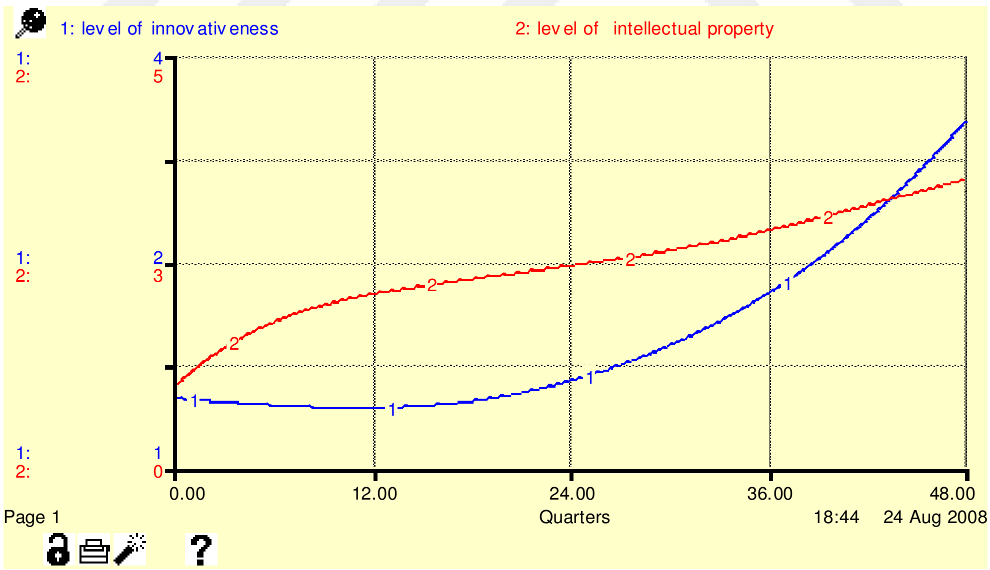

Figure 5.73 Innovativeness and intellectual property

It is seen that there is not a significant change in innovativeness and IP with the previous case. As it is mentioned earlier, sensitivity analysis is the study of how the variation (uncertainty) in the output of a model can be apportioned to different sources of variation in the input of a model. Sensitivity analysis shows important insights. It is seen that starting level of innovativeness plays a great role in the model. When there is an important difference between the firm and its competitor, the firm can not survive in the long run. Decrease fractions of stocks are so critical. Moreover, phase difference is the most important insight gained by sensitivity analysis.

5.4 Extension of the Model

In this section, a negative loop for human capital is added to the model in order to see the pattern. Negative loop for human capital decrease can be seen in Figure 5.74. As the talent level of the employees increase in a firm, competition will increase and this will increase attractiveness of the firm. This causes competition in the firm and so that collaboration decreases in the firm which will end with unsatisfaction of the employees.

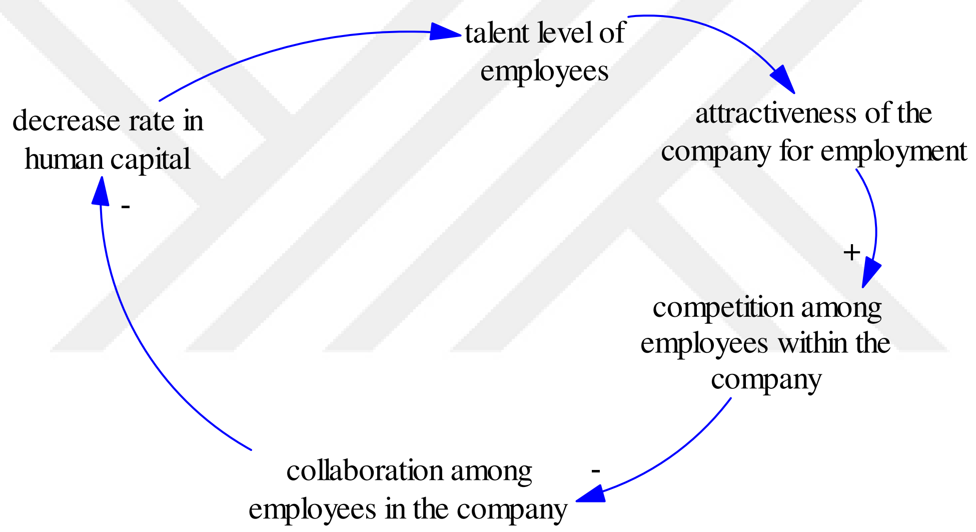

Figure 5.74 Negative loop for human capital

When we add a negative loop for human capital results can be seen below. In this case, we see that firstly innovativeness decreases until 24th quarter slightly, then it increases.

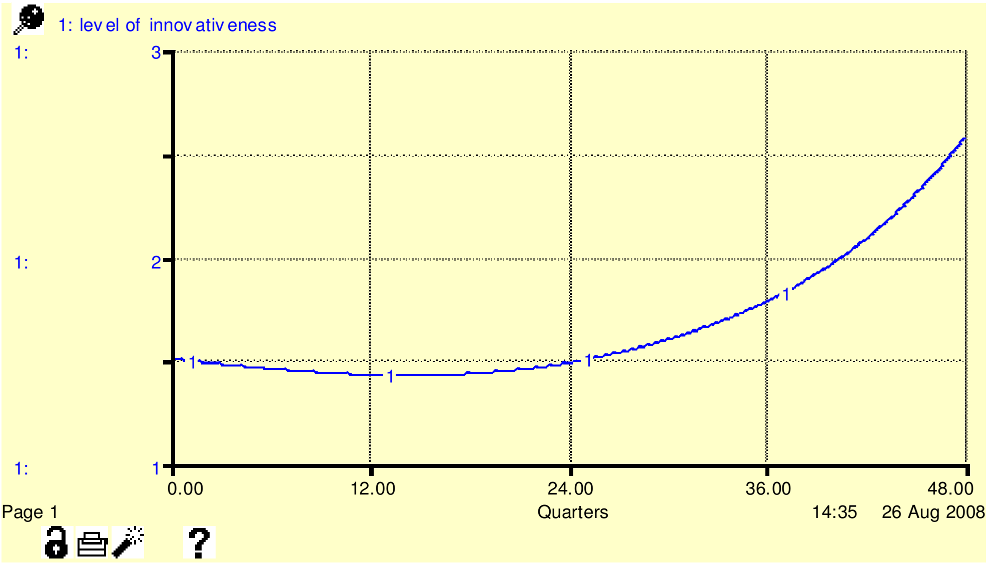

Figure 5.75 Innovativeness with negative loop

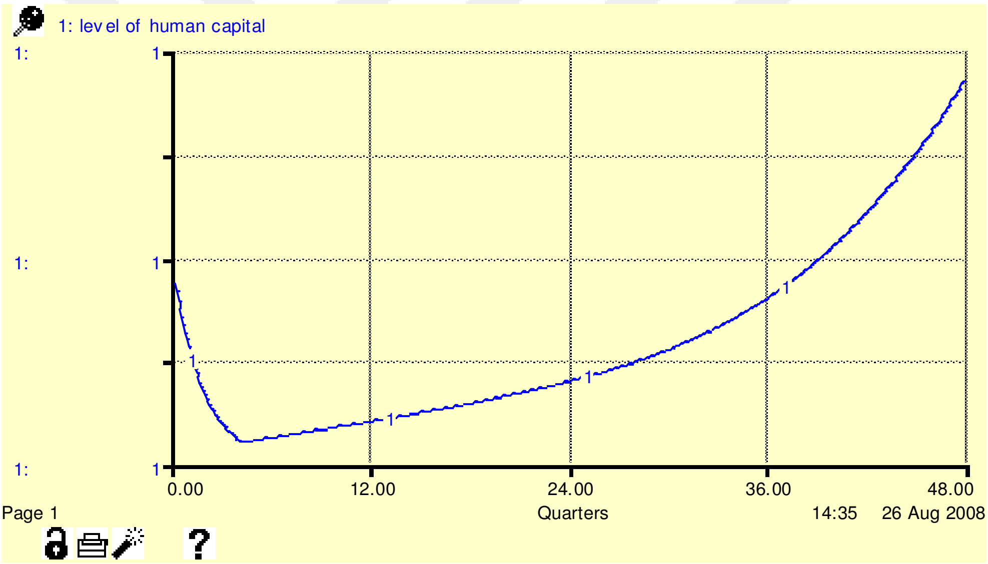

Figure 5.76 Human capital with negative loop

In the figure above displays the pattern of the human capital. Human capital decreases until 4th quarter.

Table 5.35 Stock values with negative loop

negative loop

21:35 26/08/2008 humaninnovativeness values (negative loop)

Quarters	level of huma	level of innov
.0	1.00	1.00
4.0	0.66	0.97
8.0	0.63	0.94
12.0	0.66	0.92
16.0	0.68	0.91
20.0	0.71	0.93
24.0	0.74	0.96
28.0	0.77	1.01
32.0	0.82	1.09
36.0	0.88	1.21
40.0	0.97	1.36
44.0	1.09	1.58
Final	1.26	1.88

If we make sensitivity analysis with the collaboration decrease fraction between 0.01-0.1 for 5 runs, the results are below.

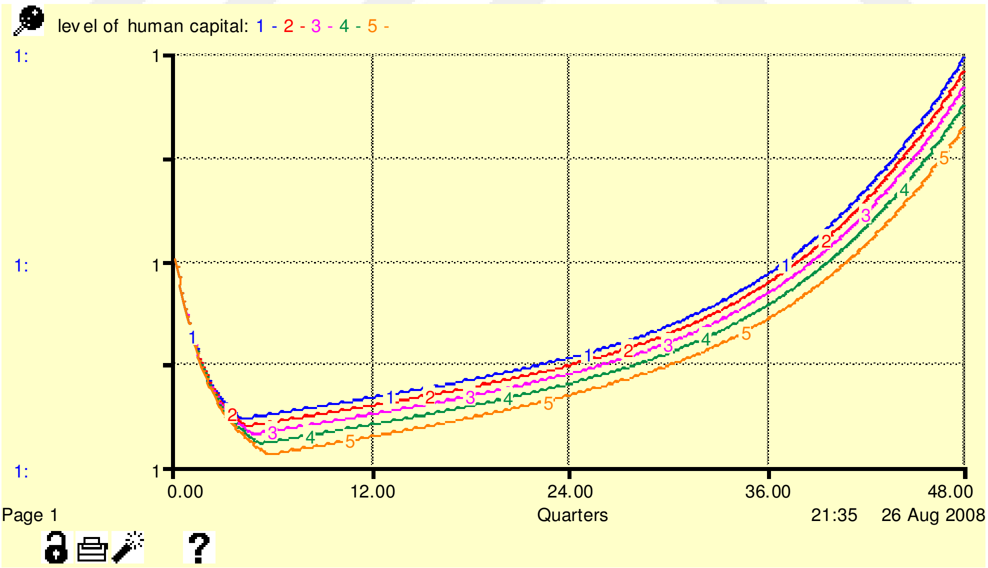

Figure 5.77 Human capital

In the model there is negative relationship between collaboration and decrease rate of human capital. In this case, human capital decreases in the first 6 quarters, then with the effect of positive factors in the model level of human capital increases. It is seen that when the decrease fraction of collaboration is 0.01, level of human capital reaches a better value.

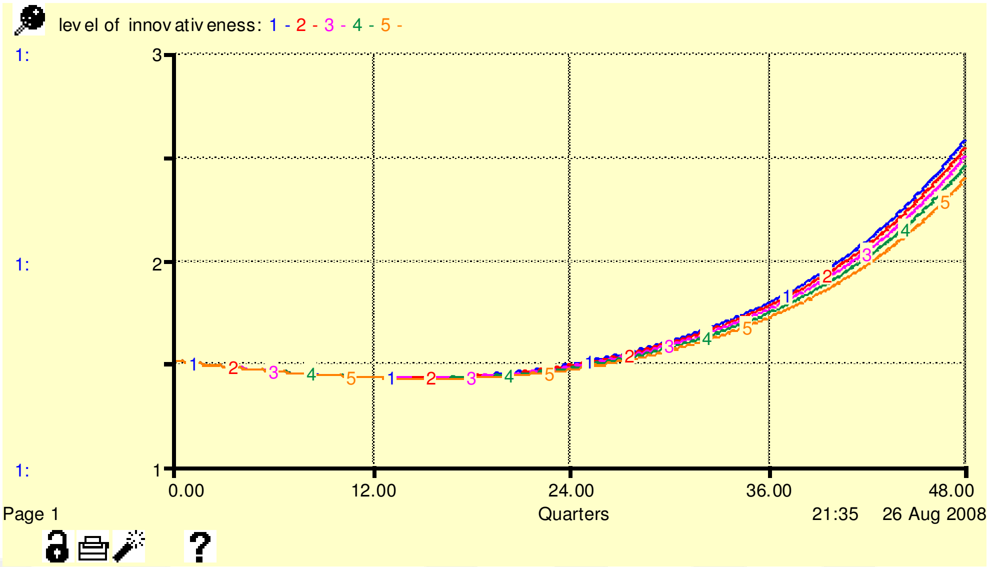

Figure 5.78 Level of innovativeness

This change also can be seen in the level of innovativeness. Phase difference can be seen. In the long run, innovativeness is affected after 18 quarters. Negative loop for human capital affects the model results but positive affects can compensate for this negative affect. This loop shows the importance of the negative factors of the innovativeness.

CHAPTER 6

CONCLUSION AND FUTURE STUDY

The purpose of the study is to build a representative dynamic model of innovation strategies. Innovation is a very complex process which is propelled by numerous factors. The pressures of globalization have brought innovation to the fore as a key element in underpinning industrial competitiveness. Innovation can be about the successful exploitation of new ideas, new products or improved business models.

System dynamics approach is chosen since it is a very useful tool for exploring the causality between innovation determinants, innovativeness.

In this model, firm culture and IP are mainly modeled conceptually. The main contribution of this thesis is presenting the innovation strategies with a causal loop diagram conceptually. In this diagram relations can be seen and loops are generated. After presenting the model by a causal loop diagram then it is converted to stock flow diagram by using Stella software. In the stock flow diagram variables can be seen in detail. Finally results are analyzed by making sensitivity analysis. It is seen that initial innovativeness level is a critical variable in the model. Firms should start a definite initial level of innovativeness in order to survive in the long run. Moreover, decrease fractions of the stocks play an important role in the results, which implies that negative factors should also be modeled in this model. Another important insight is the phase difference between variables of the model.

Briefly, this thesis forms a basis for the future studies in modeling innovation dynamics by using system dynamics methodology.

For future research negative loops can be added to the model so that increasing functions can be inhibited. Human capital is a significant variable in the model. Modeling human capital decrease fraction is an alternative for a negative loop. Figure 5.45 explains the causality below.

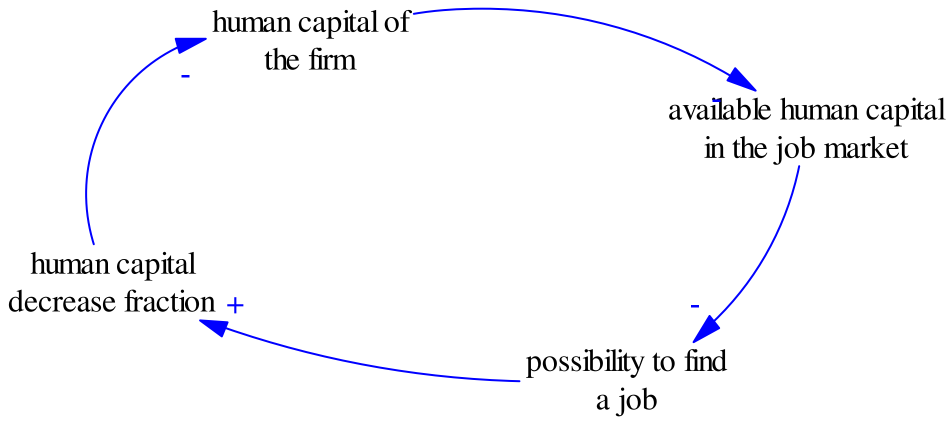

Figure 6.1 Negative loop for human capital decrease

As the human capital of the firm increases available human capital in the job market decreases and there is a negative relationship between the available human capital and possibility to find a job. When the possibility to find a job increases this case increases the human capital decrease fraction and firm loses its human capital.

Alternative for negative loop is related with IP. In other words as the available IP decreases the IP purchase becomes ineffective.

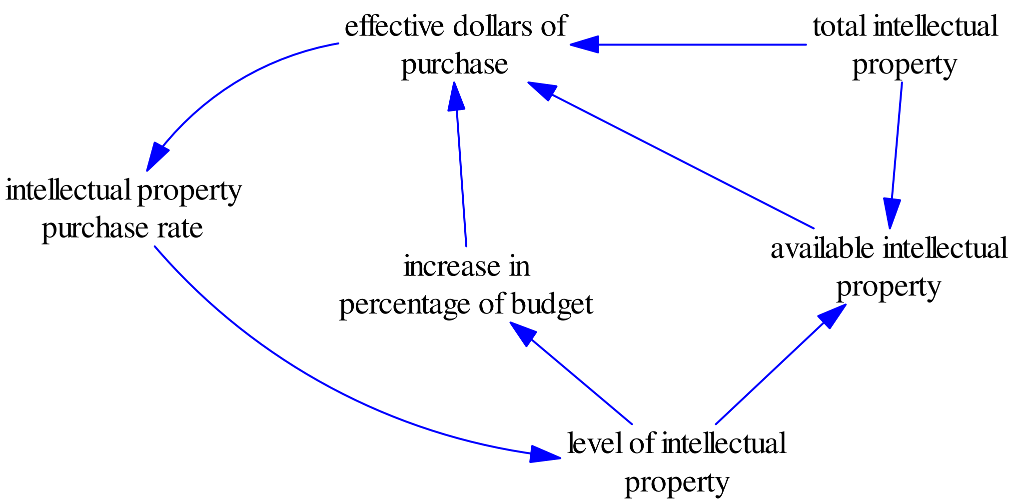

Figure 6.2 Intellectual property loop

In this model, budget for innovation is assumed as one. Furthermore, percentages of innovation dynamics can be made as decisions. In this case according to level of IP level rule can be embedded into the equations. If the ratio of level of IP and reference level value is smaller than 1 then percentage of budget should be increased. The stock flow diagram of this allocation can be seen in Appendix D. Finally, base run of the stock values can be embedded into the reference level values so that behaviors can be analyzed.

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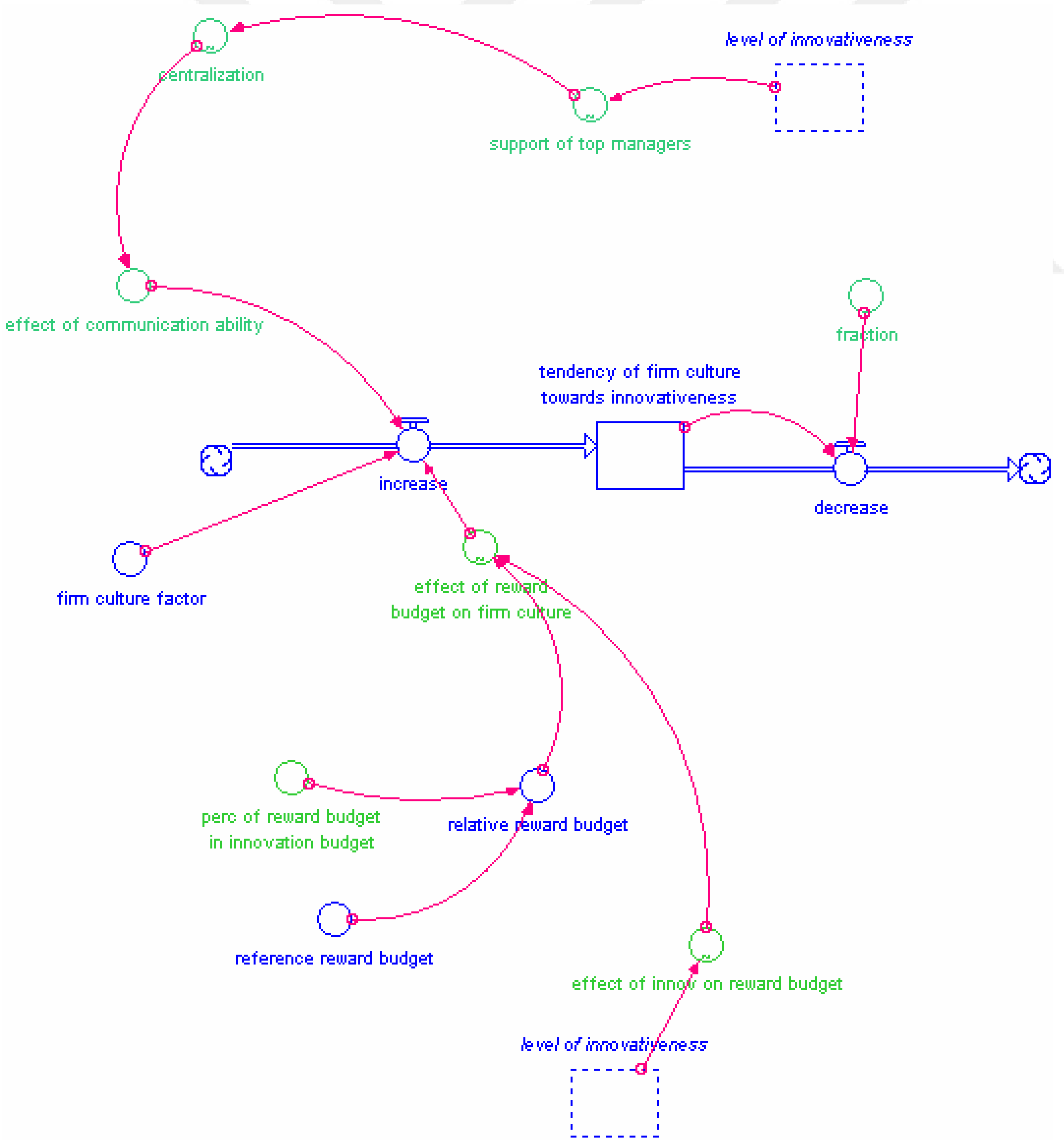
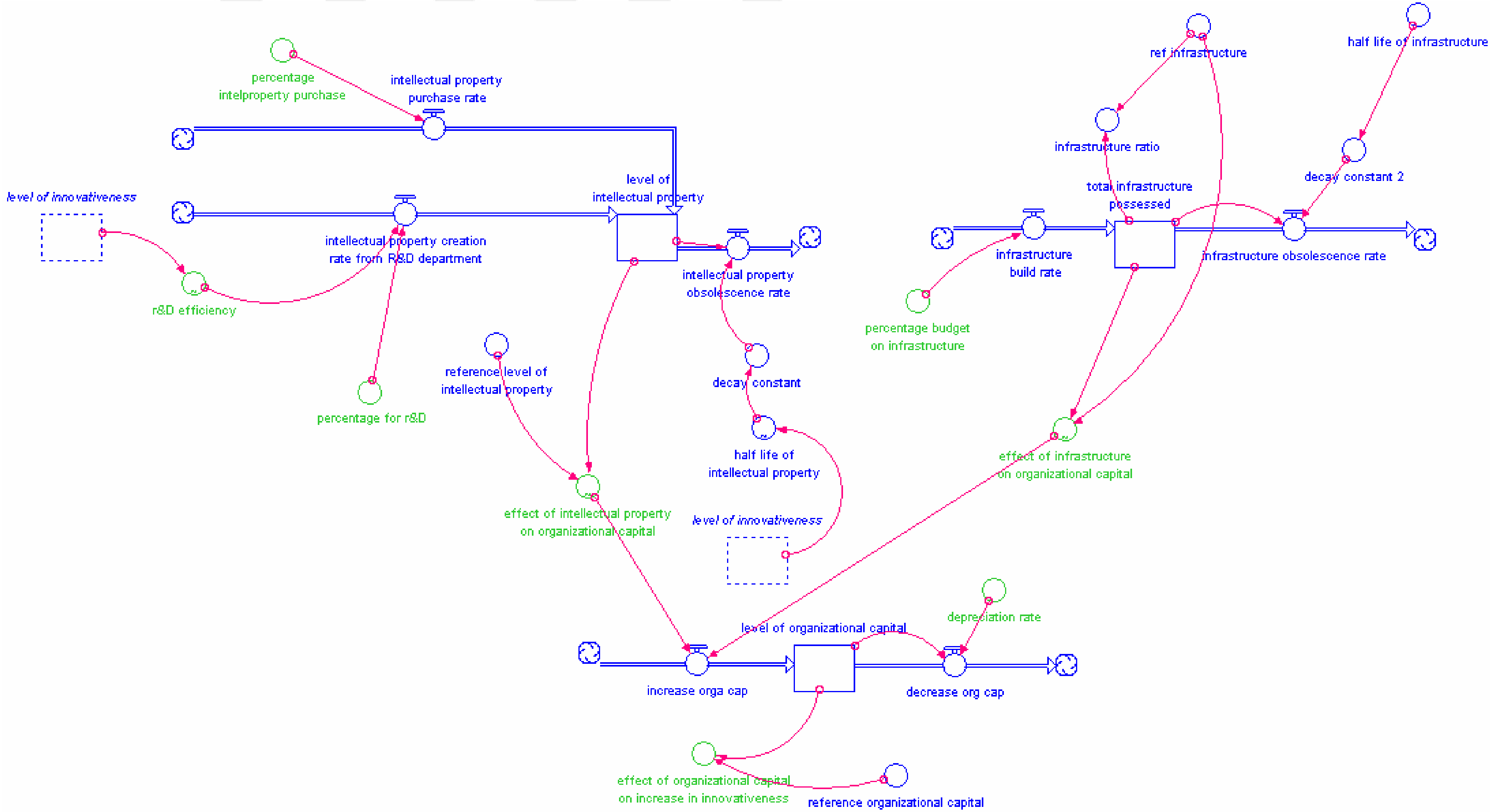
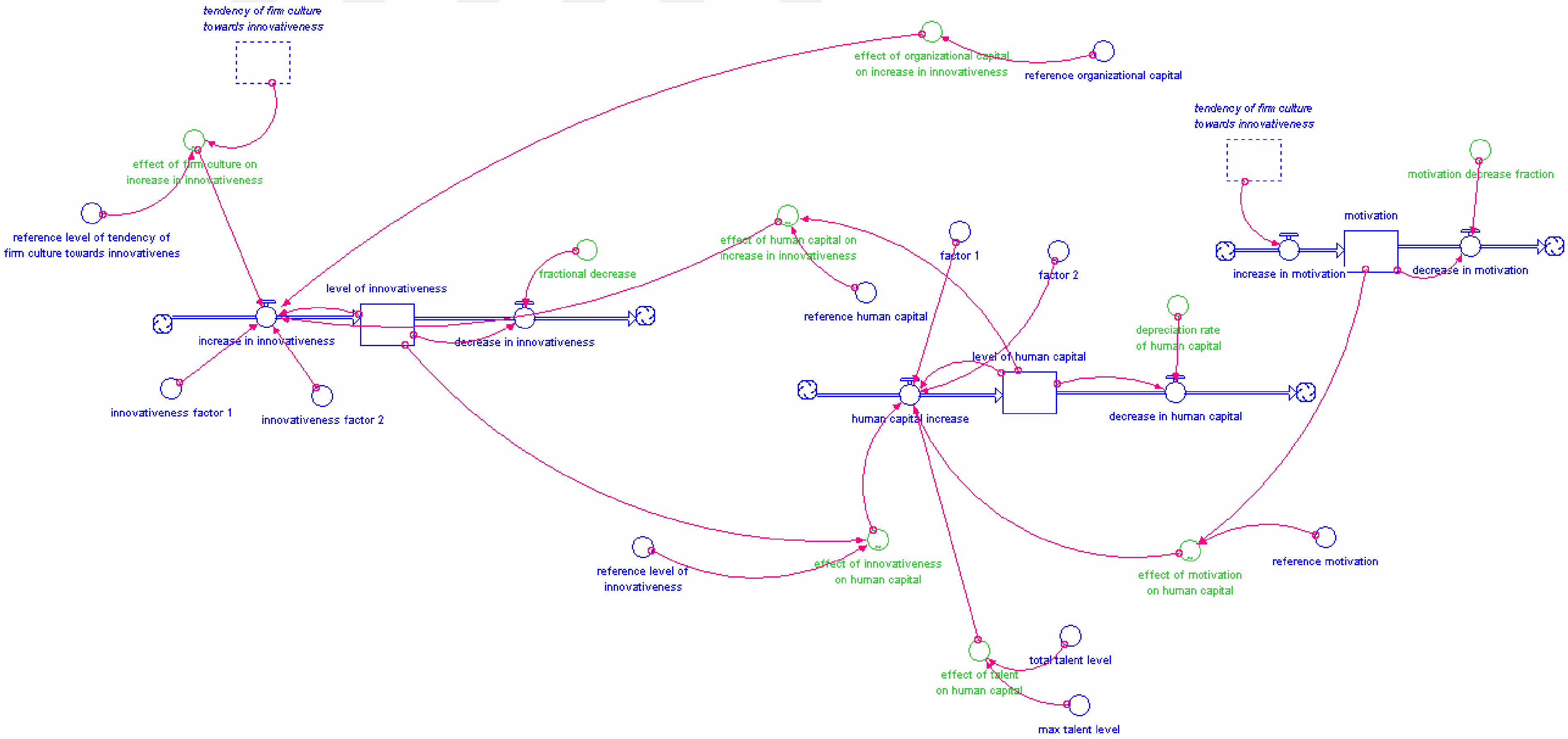
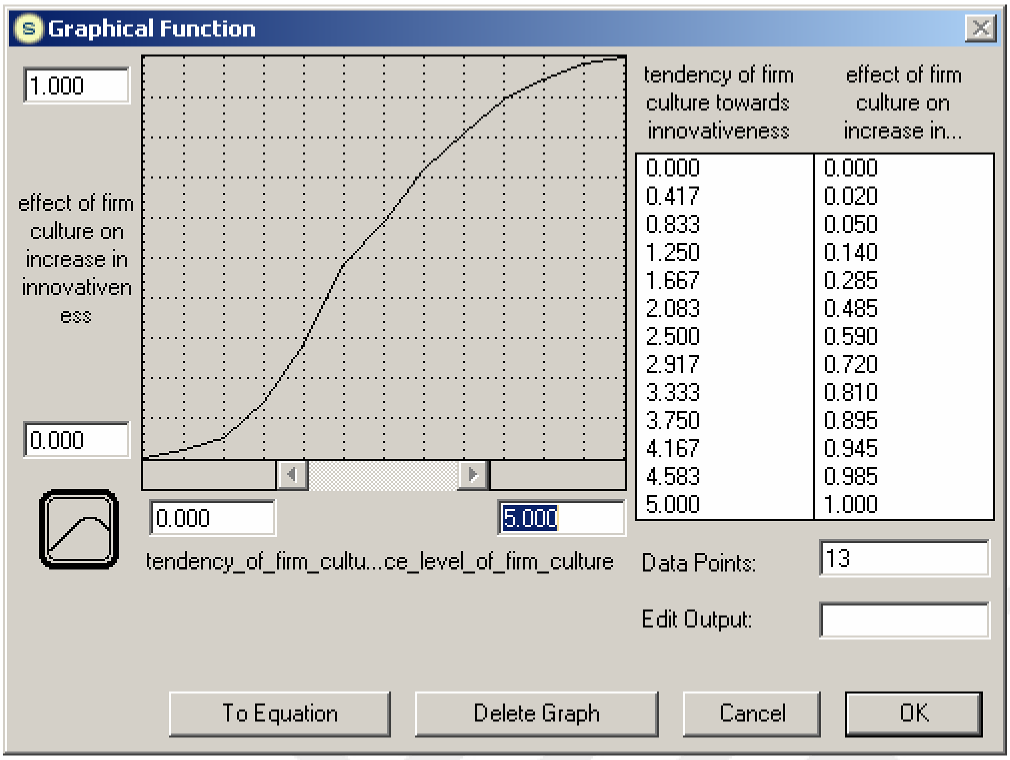
APPENDIX A: The Stock Flow Diagram of the Model

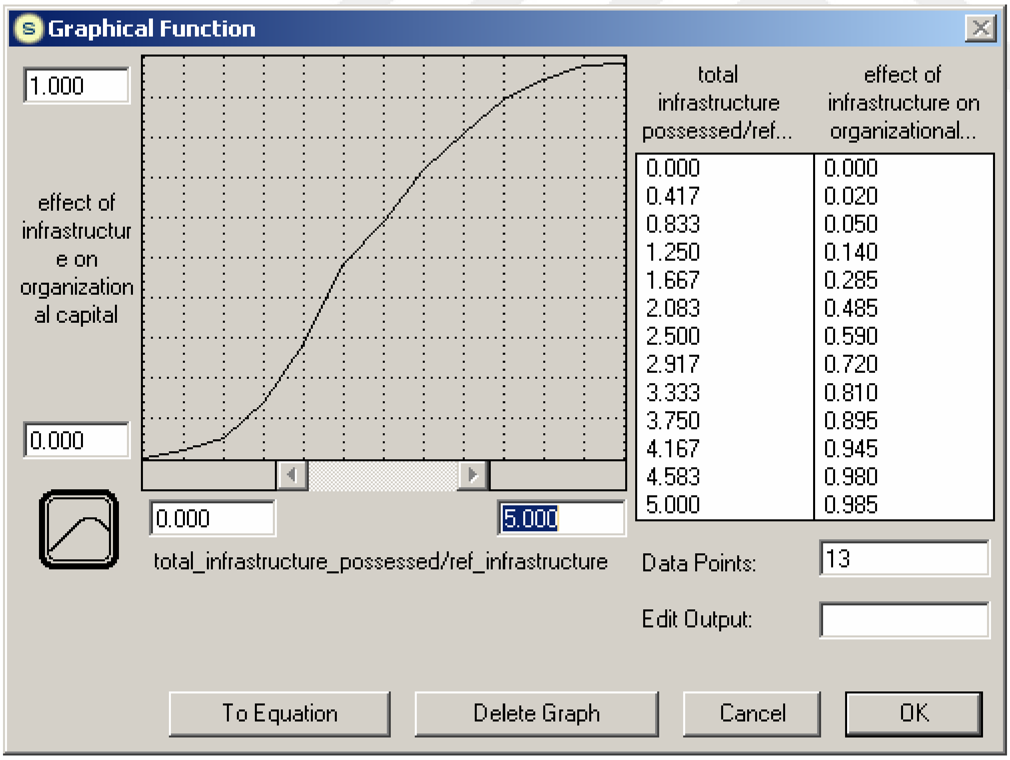


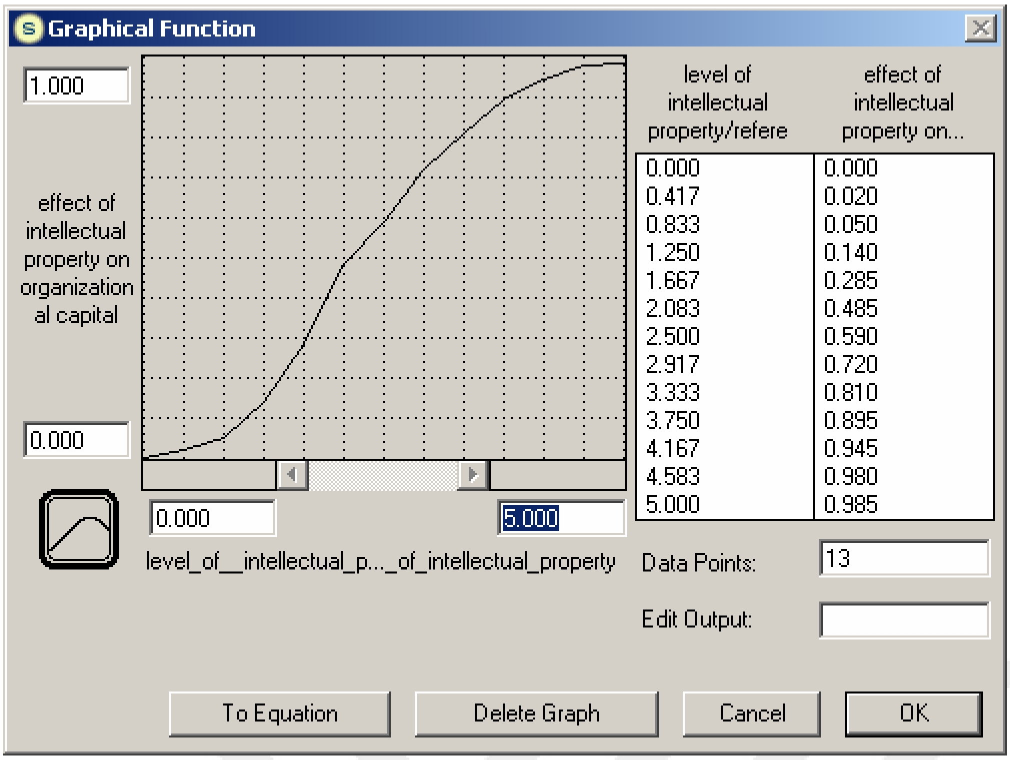

percentage
intelproperty purchase
intellectual property
purchase rate
level of innovativeness
level of
intellectual property
intellectual property creation
rate from R&D department
r&D efficiency
intellectual property
obsolescence rate
percentage for r&D
reference level of
intellectual property
decay constant
half life of
intellectual property
effect of intellectual property
on organizational capital
level of innovativeness
ref infrastructure
half life of infrastructure
infrastructure ratio
decay constant 2
total infrastructure
possessed
infrastructure
build rate
infrastructure obsolescence rate
percentage budget
on infrastructure
effect of infrastructure
on organizational capital
depreciation rate
level of organizational capital
increase orga cap
decrease org cap
effect of organizational capital
on increase in innovativeness
reference organizational capital

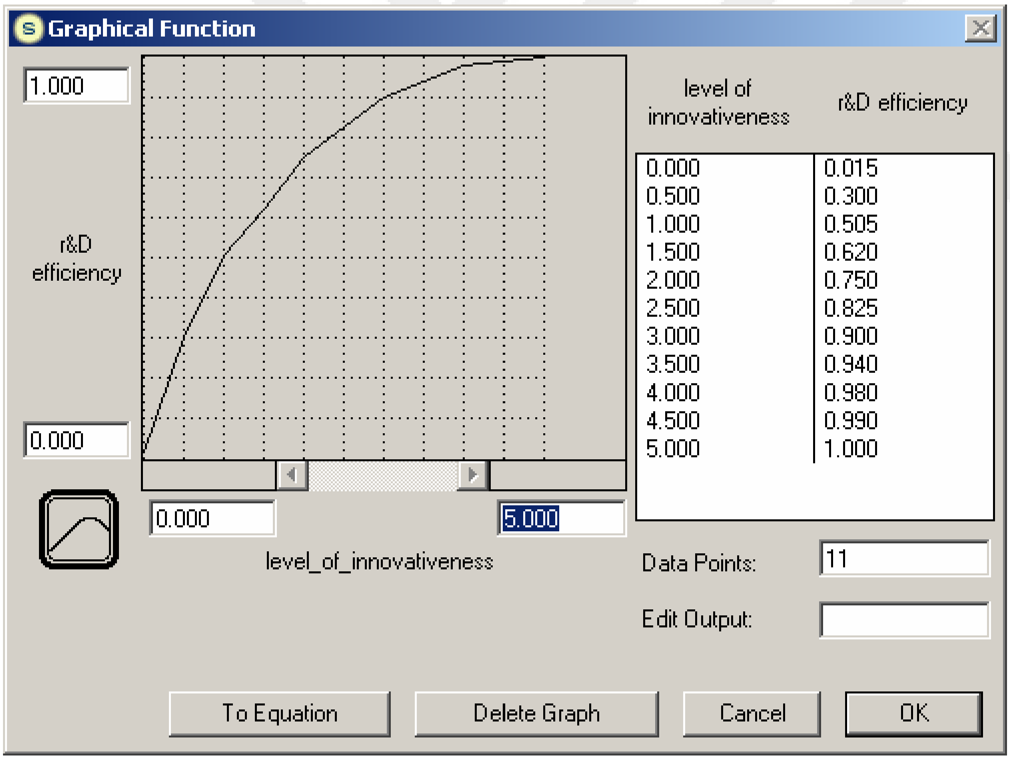

tendency of firm culture towards innovativeness
effect of organizational capital on increase in innovativeness
reference organizational capital
tendency of firm culture towards innovativeness
effect of firm culture on increase in innovativeness
motivation decrease fraction
reference level of tendency of firm culture towards innovativenes
effect of human capital on increase in innovativeness
motivation
factor 1
factor 2
increase in motivation
decrease in motivation
fractional decrease
level of innovativeness
reference human capital
increase in innovativeness
decrease in innovativeness
depreciation rate of human capital
level of human capital
innovativeness factor 1
innovativeness factor 2
human capital increase
decrease in human capital
reference level of innovativeness
effect of innovativeness on human capital
reference motivation
effect of motivation on human capital
total talent level
effect of talent on human capital
max talent level

APPENDIX B: Graphical Functions






Graphical Function
1.000
effect of intellectual property on organizational capital
0.000
0.000
5.000
level_of__intellectual_p..._of_intellectual_property
level of intellectual property/refere
effect of intellectual property on...
0.000 0.000
0.417 0.020
0.833 0.050
1.250 0.140
1.667 0.285
2.083 0.485
2.500 0.590
2.917 0.720
3.333 0.810
3.750 0.895
4.167 0.945
4.583 0.980
5.000 0.985
Data Points: 13
Edit Output:
To Equation
Delete Graph
Cancel
OK


Graphical Function
1.000
r&D efficiency
0.000
0.000
5.000
level_of_innovativeness
level of innovativeness
r&D efficiency
0.000 0.015
0.500 0.300
1.000 0.505
1.500 0.620
2.000 0.750
2.500 0.825
3.000 0.900
3.500 0.940
4.000 0.980
4.500 0.990
5.000 1.000
Data Points: 11
Edit Output:
To Equation
Delete Graph
Cancel
OK

APPENDIX C: Model Detail Equations
level_of_human_capital(t) = level_of_human_capital(t - dt) + (human_capital_increase - decrease_in_human_capital) * dtINIT level_of_human_capital = 1
INFLOWS:
human_capital_increase = level_of_human_capital/factor_1 + (effect_of_talent_on_human_capital * effect_of_innovativeness_on_human_capital* effect_of_motivation_on_human_capital)/factor_2
OUTFLOWS:
decrease_in_human_capital = level_of_human_capital*depreciation_rate_of_human_capital
level_of_innovativeness(t) = level_of_innovativeness(t - dt) + (increase_in_innovativeness - decrease_in_innovativeness) * dtINIT level_of_innovativeness = 1
INFLOWS:
increase_in_innovativeness = 0*level_of_innovativeness/innovativeness_factor_1+ (effect_of_firm_culture_on_increase_in_innovativeness*effect_of_human_capital_on_increase_in_innovativeness*effect_of_organizational_capital_on_increase_in_innovativeness)/ innovativeness_factor_2
OUTFLOWS:
decrease_in_innovativeness = level_of_innovativeness*fractional_decrease
level_of_organizational_capital(t) = level_of_organizational_capital(t - dt) + (increase_orga_cap - decrease_org_cap) * dtINIT level_of_organizational_capital = 1
INFLOWS:
increase_orga_cap = effect_of_infrastructure_on_organizational_capital*effect_of_intellectual_property_on_organizational_capital
OUTFLOWS:
decrease_org_cap = level_of_organizational_capital*depreciation_rate
level_of__intellectual_property(t) = level_of__intellectual_property(t - dt) + (intellectual_property_purchase_rate + intellectual_property_creation_rate_from_R&D_department - intellectual_property_obsolescence_rate) * dtINIT level_of__intellectual_property = 1
INFLOWS:
intellectual_property_purchase_rate = percentage_intelproperty_purchase
intellectual_property_creation_rate_from_R&D_department = (r&D_efficiency*DELAY(percentage_for_r&D,4))/2
OUTFLOWS:
intellectual_property_obsolescence_rate = level_of__intellectual_property*decay_constant
motivation(t) = motivation(t - dt) + (increase_in_motivation - decrease_in_motivation) * dtINIT motivation = 1
INFLOWS:
increase_in_motivation = tendency_of_firm_culture_towards_innovativeness/100
OUTFLOWS:
decrease_in_motivation = motivation*motivation_decrease_fraction
tendency_of_firm_culture_towards_innovativeness(t) = tendency_of_firm_culture_towards_innovativeness(t - dt) + (increase - decrease) * dtINIT tendency_of_firm_culture_towards_innovativeness = 1
INFLOWS:
increase = (effect_of_communication_ability*effect_of_reward_budget_on_firm_culture)/firm_culture_factor
OUTFLOWS:
decrease = tendency_of_firm_culture_towards_innovativeness*fraction
total_infrastructure_possessed(t) = total_infrastructure_possessed(t - dt) + (infrastructure__build_rate - infrastructure_obsolescence_rate) * dtINIT total_infrastructure_possessed = 1
INFLOWS:
infrastructure__build_rate = percentage_budget_on_infrastructure

OUTFLOWS:
infrastructure_obsolescence_rate = total_infrastructure_possessed*decay_constant_2
decay_constant = LOGN(2)/half_life_of_technology_stock
decay_constant_2 = IF(half_life_of_technology_stock_2=4) THEN 0.16 ELSE IF (half_life_of_technology_stock_2=6) THEN 0.11 ELSE 0.06
depreciation_rate = 0.01
depreciation_rate_of_human_capital = 0.01
effect_of_communication_ability = 1-centralization
effect_of_organizational_capital_on_increase_in_innovativeness = level_of_organizational_capital/reference_organizational_capital
effect_of_talent_on_human_capital = total_talent_level/max_talent_level
factor_1 = 100
factor_2 = 10
firm_culture_factor = 5
fraction = 0.01
fractional_decrease = 0.01
half_life_of_technology_stock_2 = 10
infrastructure_ratio = total_infrastructure_possessed/ref_infrastructure
innovativeness_factor_1 = 1000
innovativeness_factor_2 = 100
max_talent_level = 5
motivation_decrease_fraction = 0.01
percentage_budget_on_infrastructure = 0.3
percentage_for_r&D = 0.4
percentage_intelproperty_purchase = 0.2
perc_of_reward_budget_in_innovation_budget = 0.1
reference_human_capital = 1
reference_level_of_firm_culture = 1
reference_level_of_intellectual_property = 1
reference_motivation = 1
reference_organizational_capital = 1
reference_reward_budget = 0.1
ref_infrastructure = 1
relative_reward_budget = perc_of_reward_budget_in_innovation_budget/reference_reward_budget
total_talent_level = normal(5,2)
centralization = GRAPH(support_of_top_managers)
(0.00, 0.995), (0.1, 0.79), (0.2, 0.48), (0.3, 0.355), (0.4, 0.22), (0.5, 0.15), (0.6, 0.09), (0.7, 0.04), (0.8, 0.04), (0.9, 0.025), (1, 0.02)
effect_of_firm_culture_on_increase_in_innovativeness = GRAPH(tendency_of_firm_culture_towards_innovativeness/reference_level_of_firm_culture)
(0.00, 0.00), (0.417, 0.02), (0.833, 0.05), (1.25, 0.14), (1.67, 0.285), (2.08, 0.485), (2.50, 0.59), (2.92, 0.72), (3.33, 0.81), (3.75, 0.895), (4.17, 0.945), (4.58, 0.985), (5.00, 1.00)
effect_of_human_capital_on_increase_in_innovativeness = GRAPH(level_of_human_capital/reference_human_capital)
(0.00, 0.00), (0.417, 0.14), (0.833, 0.4), (1.25, 0.585), (1.67, 0.695), (2.08, 0.775), (2.50, 0.845), (2.92, 0.905), (3.33, 0.94), (3.75, 0.98), (4.17, 0.995), (4.58, 0.995), (5.00, 0.995)
effect_of_infrastructure_on_organizational_capital = GRAPH(total_infrastructure_possessed/ref_infrastructure)
(0.00, 0.00), (0.417, 0.02), (0.833, 0.05), (1.25, 0.14), (1.67, 0.285), (2.08, 0.485), (2.50, 0.59), (2.92, 0.72), (3.33, 0.81), (3.75, 0.895), (4.17, 0.945), (4.58, 0.98), (5.00, 0.985)
effect_of_innovativeness_on_human_capital = GRAPH(level_of_innovativeness)
(0.00, 0.035), (0.5, 0.105), (1.00, 0.23), (1.50, 0.535), (2.00, 0.78), (2.50, 0.885), (3.00, 0.93), (3.50, 0.975), (4.00, 0.995), (4.50, 1.00), (5.00, 1.00)

effect_of_innov_on_reward_budget = GRAPH(level_of_innovativeness)
(0.00, 0.2), (0.5, 0.64), (1.00, 1.00), (1.50, 1.00), (2.00, 1.00), (2.50, 1.00), (3.00, 1.00), (3.50, 1.00), (4.00, 1.00), (4.50, 1.00), (5.00, 1.00)
effect_of_intellectual_property_on_organizational_capital = GRAPH(level_of__intellectual_property/reference_level_of_intellectual_property)
(0.00, 0.00), (0.417, 0.02), (0.833, 0.05), (1.25, 0.14), (1.67, 0.285), (2.08, 0.485), (2.50, 0.59), (2.92, 0.72), (3.33, 0.81), (3.75, 0.895), (4.17, 0.945), (4.58, 0.98), (5.00, 0.985)
effect_of_motivation_on_human_capital = GRAPH(motivation/reference_motivation)
(0.00, 0.00), (0.5, 0.14), (1.00, 0.4), (1.50, 0.585), (2.00, 0.695), (2.50, 0.775), (3.00, 0.845), (3.50, 0.905), (4.00, 0.94), (4.50, 0.98), (5.00, 0.995)
effect_of_reward_budget_on_firm_culture = GRAPH(relative_reward_budget*effect_of_innov_on_reward_budget)
(0.00, 0.05), (0.1, 0.09), (0.2, 0.23), (0.3, 0.36), (0.4, 0.62), (0.5, 0.765), (0.6, 0.885), (0.7, 0.96), (0.8, 0.975), (0.9, 0.99), (1, 1.00)
half_life_of_technology_stock = GRAPH(level_of_innovativeness)
(0.00, 1.00), (0.5, 1.50), (1.00, 5.00), (1.50, 13.0), (2.00, 21.0), (2.50, 35.5), (3.00, 50.0), (3.50, 70.5), (4.00, 92.0), (4.50, 98.0), (5.00, 100)
r&D_efficiency = GRAPH(level_of_innovativeness)
(0.00, 0.015), (0.5, 0.3), (1.00, 0.505), (1.50, 0.62), (2.00, 0.75), (2.50, 0.825), (3.00, 0.9), (3.50, 0.94), (4.00, 0.98), (4.50, 0.99), (5.00, 1.00)
support_of_top_managers = GRAPH(level_of_innovativeness)
(0.00, 0.015), (0.5, 0.41), (1.00, 0.66), (1.50, 0.775), (2.00, 0.82), (2.50, 0.855), (3.00, 0.89), (3.50, 0.915), (4.00, 0.945), (4.50, 0.965), (5.00, 0.995)

APPENDIX D: Stock Flow Diagram of Budget Rules