A System Dynamics Approach for Technology Improvement Policy Analysis: The Case for Turkey

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STPS – WP - 0304

ABSTRACT

Technology has been one of the most important factors of the economic and social growth and globally scaled competitiveness, although not respected as a separate factor by traditional economists until recently. It is now widely accepted that technology improvement plays a very major role on national growth. Technology has a number of interactive and conflicting variables and parameters, which are not allowing an analysis with quantitative tools only. Complex dynamic analysis seems to be a proper tool to handle this sophistication. A system dynamics model constructed for policy analysis in Turkey with respect to technology improvement and comparison of various technology improvement policies. Under the scope of this paper; the elements effecting technology improvement are identified and analyzed by qualitative/quantitative methods, the key relations among these elements are identified, the influence model and the system model are drawn and some scenario analysis are performed for the comparison of possible technology improvement policies.

Keywords: System Dynamics, Economic Growth, Technological Capability, Technology Improvement, Technology Policies.
JEL Codes: 033 , M54, L86

1. INTRODUCTION

As technology is the main source of national growth, all countries should have technology improvement policies to support their national growth policies. In fact, compared to other policies, technology improvement policies may be the toughest one as it has many interactions with many variables.

Technology is the most vital parameter of culture and industrial progress. Thus it requires sensitive management, good strategic planning and policy identification. As technology improvement has high and wide interactions with all social, economic and technical terms, dynamic analysis arises as a necessity. Dynamic analysis is a sophisticated mathematical concept.

System Dynamics is a rigorous method for qualitative description, exploration and analysis of complex systems in terms of their processes, information, organizational boundaries and strategies; which facilitates quantitative simulation modeling and analysis for the design of system structure and control (E. F. Wolstenholme, 1990).

Since publication of J. W. Forrester's classical books "Principal of Systems" in 1958, and "Industrial Dynamics" in 1961, the application field of system dynamics has grown in more than thirty countries around the world. Computer simulation models developed and used for solving the complex equations on various issues from the micro concerns of biology to the macro concerns of national and global economics.

The name "Industrial Dynamics" soon changed to the more general term "System Dynamics". The problems dealt by System Dynamics have at least two features in common: they are dynamic and have feedback systems.

Since the last decades the methods of System Dynamics have been applied to wider range of problems from managing the R&D projects to analyzing the government policy alternatives.

Technology is a dynamic system and changes over time so that System Dynamics appears to be a potential tool to determine the technology improvement policies.

System Dynamics is a proper and valid tool for policy analysis, therefore in this paper System Dynamics will be used to model the important dynamics of technological impacts on social and economic development in Turkey and to evaluate different technology policy alternatives. Even though system dynamics method is widely used for policy identification/analysis, it is very hard to find system dynamics studies for technology improvement policy making in Turkey.

This paper is aiming to model the important dynamics of the technological impact on social and economic development in Turkey and to evaluate different technology policy alternatives.

2. TECHNOLOGY & TECHNOLOGY IMPROVEMENT POLICY

Technology should not refer only to high-tech or science, engineering and mathematics. Technology covers more than machines, processes and inventions. Technology has many descriptions; some are very simple and others are very complex.

Here are some descriptions of technology (Gerard H. Gaynor, 1996);

- Technology is the means for accomplishing a task-it includes whatever is needed to convert resources into products or services.
- Technology includes the knowledge and resources that are required to achieve an objective
- Technology is the body of scientific and engineering knowledge, which can be applied in the design of products and/or processes or in the search for new knowledge.

Technology and science have turned to be direct productive powers and this is the distinguishing characteristic of the 20th century. Capability in production means capability in science and technology and vice versa. Therefore science and technology has gained strategic importance in economic development and social welfare. In addition to that fact, “science policies” of countries have become “science and technology policies” and these policies have been started to be knitted with economic and social concepts.

Managing technology can be described as the process of integrating the business unit resources and infrastructure in the fulfillment of its defined purposes, objectives, strategies and operations.

To manage technology and improve technology, the system related with the technology should be well defined, the changes by time and the feedback gathered should be well analyzed. The policies should cover the purposes, objectives, strategies and processes of technology improvement studies. All these points make the system complex and unmanageable with the classical approaches. System Dynamics can be used both for defining policies that are tested by simulations and for better decision making support.

Technology has a number of interactive and conflicting variables and parameters. In order to have a reliable and valid model, all these variables and parameters should be identified and related with each other in an appropriate form.

Technology has a cycle to be called as 'Technology Flow Process'. The steps of Technology Cycle are; Technology Awareness, Technology Acquisition, Technology Adaptation, Technology Advancement and Technology Abandonment. (Gerard H. Gaynor, 1996)

The diagram of the Technology Cycle is given in Figure 2.1.

All the interactive and conflicting variables and parameters should follow this cycle to achieve a remarkable technology improvement. On the long run, technology affects all the factors of life. Therefore technology is very important and should be managed in a well-defined manner at all scale from firm level up-to nation level.

Government intervention to support innovation requires justification. There are two primary sources of data on industrial R&D such that; government financing appropriations by socio-economic objectives and expenditures coming from surveys of enterprises complied by governments. Most of the government appropriations are for defense thus essentially for industrial development. The share of the government appropriations for industrial development is at most 20%. However the share of the government appropriations for industrial innovation is about 40%. (OECD, 1995)

THE TECHNOLOGY CYCLE:

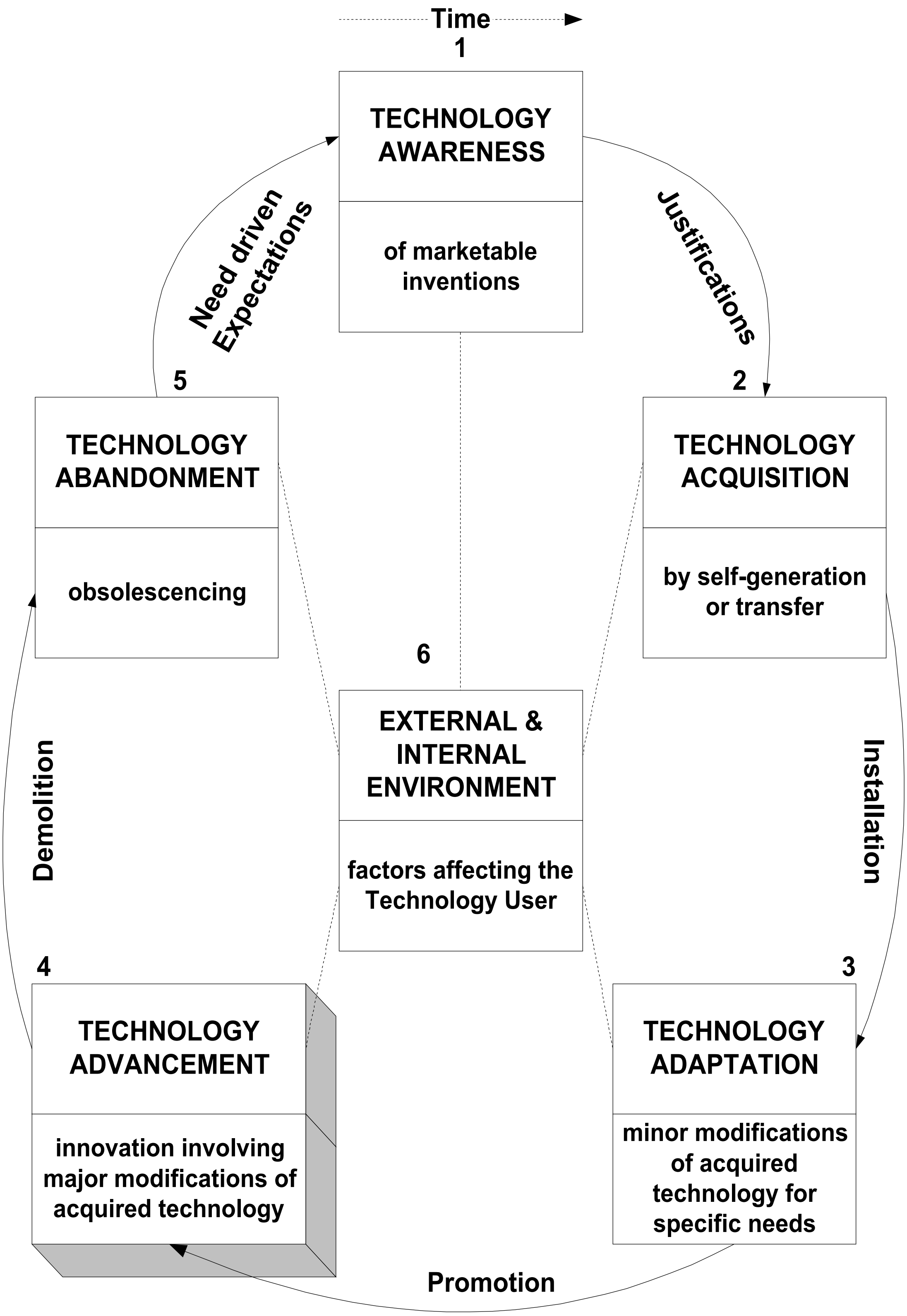

Figure 2.1: The Diagram of the Technology Cycle

A large number of national programmes have been on the promotion of strategic, generic, new or critical technologies whose success is seen as eventually having widespread effects on industrial competitiveness. Most government R&D programmes are particularly about promoting innovation and industrial competitiveness.

Government R&D budget is mainly allocated for defense objectives in the OECD countries (38.3% _ 1993). (OECD, 1995)

Technology policies are;

- mission-oriented (USA, France, UK)
- diffusion-oriented (Germany, Sweden, Switzerland) (public goods)

Japan shows characteristics of both types of policy.

In general, National Technology Programme objectives include the following;

- support to R&D in general,
- support for specific technologies, and in particular “generic” or “enabling” technologies,
- support for technologies seen to be important for non-commercial, public reasons, such as defense, social infrastructure, public health, etc,
- commercialization of R&D which government has supported for other reasons, mainly defense, energy, space and public health; and,
- wider diffusion of government-supported R&D, especially to/through SMEs and better use of national laboratories.

The choice of new technology can influence economic development of a nation and thereby the pace of nation building. Once new technologies are introduced, they will be diffused sooner or later to other companies. The speed and extent of this diffusion have critical affect on the efficiency of the national economy.

A joint venture is often important, not only to introduce new technologies but also to diffuse them. The government policies promote joint ventures between small and medium size enterprises.

The government permits for the adaptation of new technology should be given promptly in order not to delay the diffusion of the new technology. The role of government in checking the process of technology transfer is very important.

Oligopoly-dominated manufacturing produces endogenously a good part of its “normal” technological advances and apart from major crises, seems to coordinate rather well its price/quantity adjustments.

Technology utilizes science so that new industrial activities and improvement of goods and services may come true. There is close relationship between science and technology and they are connected with the feedback loops. Basic research is performed for the new scientific findings; these new findings are the inputs of the applied research, which is performed for the new technologies that initiate environmental development and prototyping. Prototype is the input of marketable new innovation that will be diffused at various markets. Market and technology needs will be the sources of the new basic researches.

Countries are trying to determine their own technology advancement/ improvement policies in order to generate technology oriented regional development.

There are heavy global strategic alliances especially in information, microelectronics, software development and telecom sectors, which are considered having high technology level.
Techno-science Park promotes new technology based firms, invention/ innovation studies & employment of qualified manpower while it is one of the main actors of national technology improvement policy.

Policies of technology management for the technology improvement should resemble the real system. As the system is dynamic and changes over time, System Dynamics appears as a major tool to determine the technology improvement policies.

3. TECHNOLOGICAL CAPABILITIES & LEVELS

Technological Capability (TC) can be defined generally as the capacity to select, assimilate, adapt and improve existing or imported technologies and create the new technology.

The characteristics of technological capabilities required to produce and/or adopt innovations efficiently also depend on the knowledge base specific to each technology. The process of technological development is strictly associated with inter and intra national diffusion of superior techniques.

The rate of economic growth of a country is positively influenced by the rate of the growth in the technological level of a country. If there is a positive relationship between the level of the technological level and economic growth of a country then technology developed in the "Less Developed Countries" (LDCs) itself should be treated differently from that developed in foreign countries; technologies have different characteristics that affect economic growth differently. The inflow of foreign technology to the industry sector of LDCs contributes substantially to the growth of the sector. The impact of the foreign technology is positive & substantially larger than the impact of the domestic technology on the industry sector of LDCs.

The acquisition and development of TC is a prerequisite for the absorption of imported technologies, the creation of more appropriate technologies, diffusion of knowledge within the economy and the efficient use of imported technologies.

National TC refers to the ability of a country to use knowledge effectively to select, assimilate, adapt, improve, diffuse and create technology and it is revealed in industrial dynamism, diversification, and competitiveness. National TC is not simply a sum of individual firms' TCs because of the externalities and interlinkages.

At the national level, getting access to relevant foreign technology also involves an adequate policy framework for direct foreign investment, technology transfer, capital goods imports, & intellectual property protection.

Economic growth and stability, trade regime and industrialization strategy, industrial policy, science and technology policy, and education and training are the determinants of TC development.

Knowledge in the industrial sector is conveyed through education and training, crucial determinants of building up TC. The adequacy of national education and training systems appears to be a crucial factor determining how effective a country's firms are in applying technological skills across the full range of their activities. The availability of educated and trained people in the appropriate disciplines is very important for industrial performance and improvement of TC.

Macroeconomic variables, incentives for competitiveness, export activity, industrial policies, foreign investment, technology policy, education and training and sector specific factors influence the improvement of TC.

Technological change refers to, according to Schumpeter's definition, to three stages: invention or the creation of the new products and processes; innovation or the commercial application of invention; and diffusion or the spread of the innovation into the economy.

4. TECHNOLOGY IMPROVEMENT POLICIES IN TURKEY

National policy studies in science and technology started with the planned economy period in Turkey. As the result of the First Five-Year Development Plan (1961-1966), establishment of TUBITAK (Scientific and Technical Research Council) in 1963 was the first step for the Science & Technology institutionalization in Turkey. TUBITAK is responsible for coordination and promotion of research in basic and applied sciences.

Turkey has to cope with many problems. The most vital one is to catch up with technological changes. As Ottoman Empire missed the evolutionary process towards an industrial society during the industrial revolution, Turkey could not surpass the industrialization threshold.

Currently, Turkey has to face the problem of overcoming this historical gap as well as keeping up with the changes in the high-tech and post-industrialization age while the industrial societies are evolving into a new era called as Information Society. The ability of Turkey to solve these problems will determine her future. Improving the scientific and technological ability of Turkey and creating a dominance of science and technology is a proposed strategic choice, which may be entitled as National Science & Technology Policy.

At the beginning of 1980’s, "Turkish Science Policy: 1983-2003" was prepared with the contribution of 300 scientists and experts. This was the first time that a detailed science and technology policy document had been prepared.

Research Priority Areas during 1980s were:

- Low Cost Industrial Automation
- Advanced Materials
- Macro-optimization of Agricultural and Forestry Production
- Optimization of Coal Utilization
- Local Production of Organic and Inorganic Chemical Materials
- Recycle of Agricultural and Industrial Wastes

During 1980s, the major technological advancements were in defense industry and telecommunication sector.

The Supreme Council has put forward some goals for the 1990s:

a) increasing the number of R&D personnel to 15 per 10,000 labor force (7.5 in 1992);
b) increasing Gross Expenditure on R&D (GERD) to 1 % of the GDP (0.5 % in 1992);
c) increasing the business enterprise’s share of R&D expenditure to 30% of the GERD (24 % in 1992);
d) raising the Turkey’s rank (38 in 1992) in journals covered by the Science Citation Index.

Taking Turkey’s capabilities and world scientific and technological trends and forecasts into account, the following generic technologies, in general, have been accepted as priority areas of activity (TUBITAK, 1999):

Informatics, advanced materials, gene engineering, biotechnology, defense technology, [aero]space technology.

In brief, the main proposition was that Turkey has to establish her "National Innovation System" with all the necessary building blocks of it in order to enhance her ability in science and technology, and to get the capability of transforming them to economic and social benefit.

Main Actors in the Technology Policy Area in Turkey are shown in Figure 4.1.

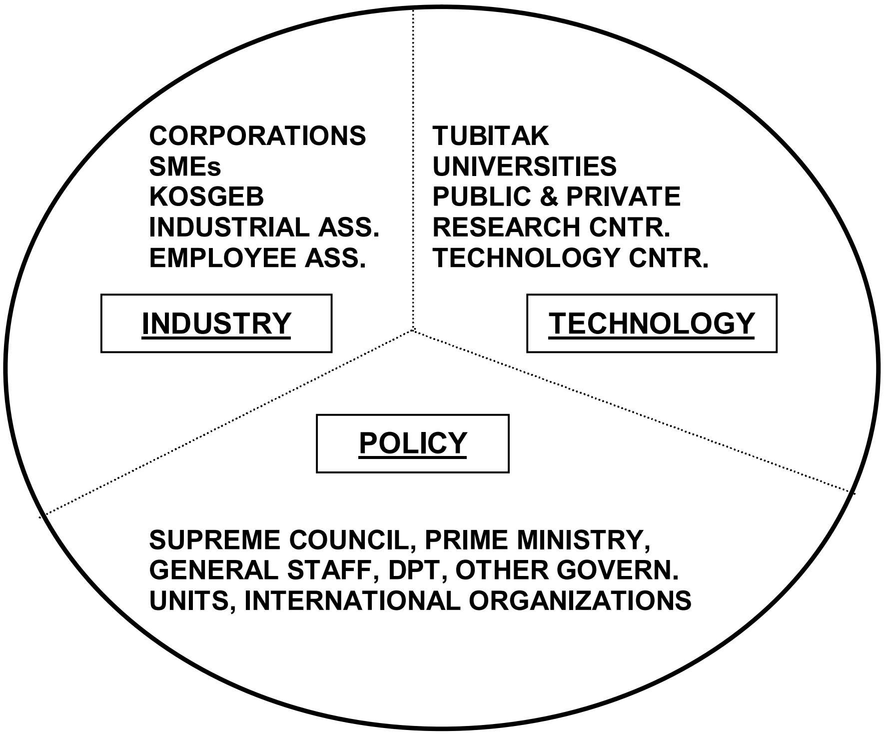

Figure 4.1: Main Actors in the Technology Policy Area in Turkey

In order to finance more advanced technological industrialization Turkey can cooperate with countries at similar development levels and sell her technology by the way of technology transfer or licensing. Simultaneously, Turkey should cooperate with technologically advanced countries to obtain developed technologies and know-how in these fields.

Turkish Government introduced the Law of Technology Development Districts, which was accepted by Turkish Assembly on June 26th, 2001 and published on official newspaper on July 6th, 2001. The goals of this law are outlined as below:

a) cooperation among universities, research institutes and industrial sector,
b) advancement of national industry competitiveness and export scoped structuring,
c) production of technological knowledge, innovation on process and product, improvement on product quality standards and productivity, reduction on production costs, commercialization of technological knowledge/data,
d) supporting technology intensive production and enterpreneurship and harmonization of small/medium size companies with new/advanced technologies,

e) creation of investment opportunities at technology intensive environment by taking into account the decisions of Science & Technology Steering Committee and job opportunities for researchers and capable people,
f) assisting technology transfer and establishment of an infrastructure for rapid penetration of foreign capital technology investment.

As it is stated in the "Science and Technology Committee" report;

- Homogeneous regional dynamics,
- Existence of the universities,
- Dynamic university-firm relationship,
- Support and willingness of the local authorities,
- Existence of directive private-governmental enterprises,
- Existence of qualified, trained workforce,
- Ease of financial support,
- Information and transportation infrastructure,
- Existence of strategic support mechanism,
- Closeness to the Research and Development Centers,
- Availability of regional networks for communication and corperation,
- Closeness to the prospective markets,

are the major factors of regional innovation systems, and thus national innovation system.

Realization of Science & Technology Progress in Turkey is the major axis of the 7th Five-Year Plan. One of the targeted goals is the increase of R&D Expenditure/GNP ratio from 0.33% to 1%. Only financial resource reservation is not enough for Science & Technology Progress and also education/training and demand are the other important issues. There should be a demand for product development design and production and this demand should be directed to Science & Technology Centers for realization in order to improve Science & Technology level of Turkey.

5. SYSTEM DYNAMICS AS A TOOL

During the 1940s, formal analysis, often involving mathematical and statistical techniques, had been applied to the problems of 2nd World War, then to the industries and business firms. They were formalized into disciplines of operational research and management science, that were excellent and powerful methods dealing with certain classes of problems. The ability of the system adjusting the status during the circumstances changes as the time passes was not the aspect of the management thus, disciplines of operational research and management science. However, the behavior of a system as time passes and new decisions have to be taken accordingly is a significant type of management problem, which requires the analyst to tackle the issues of a system reacts to dynamic elements and how those reactions shape its moves into the future. Problems can be complicated, it is necessary to have a methodology for dealing with them, and **System Dynamics** provides this methodology and it is interpreted as the branch of management science which deals with the dynamics and controllability of managed systems.

System Dynamics originated at the Massachusetts Institute of Technology in the late 1950s by Professor Jay W. Forrester. His first explanations on System Dynamics was in his classic book “Principal of Systems”, which was first published in 1958. With his book “Industrial Dynamics” a number of models of industrial problems had been developed.

Some definitions of System Dynamics;
(Forrester, 1961)

System Dynamics is the investigation of the information-feedback characteristics of managed systems and use of models for the design of improved organizational form and guiding policy.
(Coyle, 1995)

System Dynamics deal with the time-dependent behavior of managed systems with the aim of describing the system and understanding, through qualitative and quantitative models, how information-feedback governs its behavior, and designing robust information feedback structures and control policies through simulation and optimization.

System Dynamics can fundamentally improve the effectiveness of management decision making, since it was designed to model complex systems by representing the structure, processes, strategies and information flows. Therefore it can be used during the phase of policy making.

Once a conceptual appreciation has been developed for the dynamics of complex systems, meaningful simulation models can be constructed to translate those mental models into simulations. Simulations allow us to shrink space and time to see the short and long term effects of our decisions.

During the identification of technology policy, a representative model of technology environment can be prepared and what if scenarios can be implemented for better and tested decisions.

Technology Improvement Policy Evaluation will be approached in five stages: problem identification and definition, modeling, analysis of models, policy evaluation and possible future studies.

6. NATIONAL TECHNOLOGY IMPROVEMENT POLICY MODELING

Later, during the 1970s, once the importance of technology had been fully recognized, more attention had begun to be paid to strategic Technology Policy-making as it is an important issue of increasing concern in most countries now. Thus Technology Policy-makers should be supported by policy construction and analysis tools and decision support systems.

Current and past technology improvement policies that Turkey has followed have been demonstrated in previous sections. Our purpose is to employ System Dynamics approach to develop a model for technology improvement at national scale, which may serve as a decision support tool for strategic S&T policy makers.

Following an extensive literature search and interviews/discussions with experts, relationship between the entities related to technology and technology improvement policy has been shaped. Major feedback loops and concentration areas have been identified. The model is based upon mainly; the conducted literature search, opinions of experts, the advisor & the author.

Interview / discussion is one of the major qualitative research techniques. Qualitative and quantitative research techniques are complementary to each other. Thus both techniques should be used during any study to reach a more reliable conclusion. In this article both techniques had been used during the construction of the System Dynamics Modeling.

After identifying the major concentration areas and feedback loops, influence diagrams of the technology improvement policy model has been drawn. Influence Diagram of the model is given in Appendix-A. Simulation model of the technology improvement policy model could be constructed by the help of influence diagram drawn.

Although STELLA is widely used and known in the literature, System Dynamics software "iThink" is selected for the construction and analysis of the simulation model. Both STELLA and iThink software are the products / software of `High Performance Systems, Inc.' (HPS) and they are very similar to each other. "iThink" is a Microsoft Windows based simulation software package and it enables the users to represent the model and the outcomes graphically. The reasons of this selection are the user-friendly structure, availability of the software and author's familiarity with this software.

When the developed Influence Diagram is studied some concentration zones can be identified in the diagram. Experts' opinions taken and the results of the literature survey on technology were used during the identification of these concentration zones. By this way both qualitative and quantitative research/evaluation methods had been used.

These clusters are:

a) Free Technology Zones,
b) Fusion-Diffusion and Transfer of Technology,
c) Academia-Government,
d) R&D Expenditures,
e) Technological Capability of Turkey,
f) National Innovation System (NIS),

g) Product-Process Development,

h) Technology Improvement

a) Free Technology Zones

This cluster is one of the main clusters in the system. There is remarkable number of outward and inward bounds with several other clusters and individual entities. The more Government Funds allocated, the more number of Free Technology Zones can be established in the country. As they will be the sources of fusion and diffusion of technology there exits more inventive and/or innovative and ToT activities. The more corporation with multinational firms within the Zones the more fruitful the industry, thus the more competitive shall be the country. As these outcomes occur, technology will be improved in Turkey. Unfortunately currently there is no Free Technology Zone in Turkey.

b) Fusion-Diffusion and Transfer of Technology (ToT)

This cluster is one of the main clusters in the system. There is remarkable number of outward and inward bounds with several other clusters like Free Technology Zone, Technology Improvement and individual entities. Inward investment, international programs, technical co-operations and free technology zones shall be the sources of ToT. Transferred technologies can be diffused during the 'Know How' and/or 'Know Why' stages and also inward and outward investments diffuses the fused technologies. On the other hand international programs shall increase the number of strategic alliances. As a result, fusion and diffusion of technologies shall cause upgrading of technological capabilities and the improvement of technology in Turkey.

c) Academia-Government

Within this cluster there is a strong relationship between funds and labs. Availability of labs and funds are positively supporting university-industry research centers. This cluster has also strong bounds with the other clusters such as NIS, Product-Process Development and R&D Expenditure. Government, Private and International Funds are financial sources of labs, university-industry research centers and R&D Expenditures. Funds are also consumed for process and product development activities. Funds, university-industry research centers, labs are the main cornerstones of NIS. NIS is one of the affecting factor of technology improvement of Turkey.

d) R&D Expenditures

Within this cluster there is a strong relationship between funds and R&D expenditure. R&D Expenditures are directly related with Funds, Invention, Innovation and Product & Process Development. Funds and risk capital are the main resources of R&D Expenditures. R&D Expenditures are for invention, innovation and product & process development. The more expected profit from the sale of the new product and/or process, the more financial resources denoted for R&D Expenditures.

e) Technological Capability of Turkey

Within this cluster there is strong relationship with Industrial Growth, Technological Capability of Firms and NIS. As the technological capability of the firms are upgraded eventually technological capability of Turkey shall also be advanced. NIS and Strategic Alliances should also take special attention. The imported goods shall be reduced and technology improvement of Turkey shall be sustained if technological capability of Turkey advances. Although the tariff & tax revenues shall reduce, income from export shall increases as the technological capability of firms and technological capability of Turkey advance. If technological capability of Turkey advances the international competitiveness of Turkey will also increase.

f) National Innovation System (NIS)

University-Industry Research Centers, Funds, Labs and Technological capability of firms are the main sources of NIS and NIS has bounds with to main cluster such as, Technological Capability of Turkey and Technology Improvement. In order to establish NIS government-private-international funds university-industry research centers laboratories and technological capability of the firms should be well coordinated and motivated. NIS has strong positive affect on technological capability of Turkey and thus technology improvement of Turkey. Establishment of well-organized NIS definitely requires effective integration of governmental organizations, private firms and educational institutions.

g) Product-Process Development

Product-Process Development has direct links with Invention, Innovation, Labs, Technological Capability of the Firms and Upgrading Technological Capability. This cluster has also strong relationship with clusters Academia-Government and Free Technology Zones. Government, private and international funds shall be used for product-process development. Both private labs and university-government labs are used for research on product-process development. New products and/or new processes will affect output positively thus there will eventually be an output increase. But on the other hand outward investments shall reduce in country output. The purpose of product-process development should be invention, innovation of new products and/or processes, upgrading technological capability in general and of the firms. In the conclusion product-process development has indirect but positive affect on technology improvement of Turkey. An extensive product-process development capability requires well-aimed R&D Expenditure.

h) Technology Improvement

This cluster is the core of this study. NIS, Technological Capability of Turkey, Fusion-Diffusion of Technology and Industrial Growth are the direct sources of Technology Improvement. Technology improvement of Turkey can be achieved if required NIS is well evaluated and defined, new products and processes shall be invented or innovated, new processes are adapted to manufacturing processes and obsolesce technologies shall be replaced by newly fused and diffused technologies. By this way growth of Turkish Industry will be realized thus aim of technology improvement of Turkey shall be reached.

As it could be understood from the developed Influence Diagram that policy formulation for technology improvement is very difficult and sophisticated. For the formulation and modeling of the technology improvement policy simulation model, qualitative and quantitative relations of technology policy determinants have analyzed in more detail.

In the next chapter, simulation model for the technology improvement policy in Turkey and various scenarios implemented for the technology policy analysis of Turkey will be discussed respectively.

7. APPLICATION OF THE SYSTEM DYNAMICS MODEL

The purpose of the system dynamics modeling in this article is to understand technology improvement system, to identify the related entities with their effects on national technology improvement policy and to see the trend of the technology improvement in Turkey with respect to time (15 years) by simulating some possible scenarios.

Author built the 'ithink' system simulation model to understand why some behavior pattern of the technology improvement policy system is occurring and to see what might be done to alter the pattern later during the scenario simulation phase by using the influence diagram of the technology improvement system.

A reference behavior pattern, which is a graph over some period of time of variables, which best characterizes technology improvement system identified by the author for 'as is' and 'should be' statuses (HPS Software Manuel). An expected reference behavior pattern for what is and what it should be is given below.

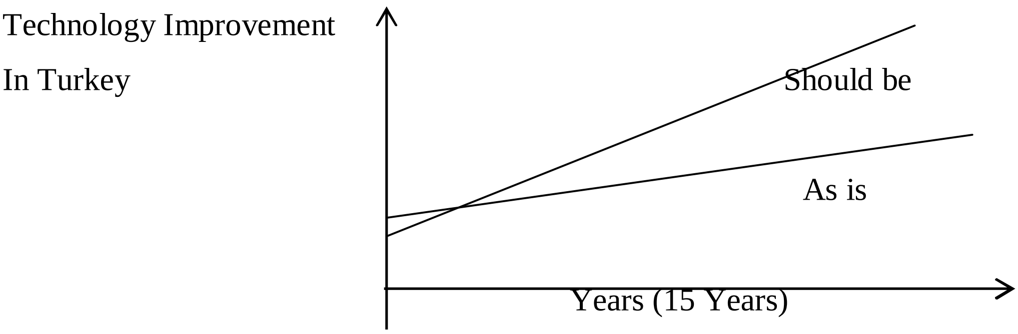

Figure 7.1: Expected Reference Behavior Pattern

By the help of developed Influence Diagram, simulation system dynamics model built. Building the simulation model begins with the development of a System Diagram, which is a high-level map of the key sectors or actors within the model and the material/information links between them. In order to develop the system diagram of the simulation model, 11 sectors have been used.

The names of the sectors and their contents are given below.

1. Outward-Inward Investment

This sector contains and calculates the figures of investments into Turkey and investments out of Turkey to the other countries and the ratio of inward to outward investment.

Base: In. Invest.: 3,050,000,000 USD Out. Invest.: 775,000,000 USD

2. R&D Expenditures

This sector contains & calculates the figures of government & private firms' R&D expenditures & the ratio of private/government R&D expenditures. Base: Gov. R&D: 624,000,000 USD Pri. R&D: 416,000,000 USD

3. Economy GNP

This sector contains and calculates the GNP figure of Turkey. The base GNP is 195 billion USD.

4. Economy Ratios

This sector contains and calculates the ratios related to GNP of Turkey, R&D expenditures and total investments.

5. Population

This sector contains and calculates the population figure of Turkey. The base population of Turkey is 65,000,000.

6. Universities

This sector contains and calculates the figures of University-Industry Research Centers (USAM), published articles in the abroad by Turkish instructors and available number of instructors in Turkey and the related ratios.

Base: Number of USAM: 12 Instructors: 22,001 Articles: 4,742

7. TUBITAK Projects

This sector contains and calculates the figures of proposed and accepted projects by TUBITAK.

Base: Proposed Projects: 933 Accepted Projects: 329

8. Education Level

This sector contains and calculates education figure of the people who have ages between 25-64 & have education higher than high school grade.

Base: Education Level: 17 %

9. Technology Value Added

This sector contains and calculates technology value added government/ private R&D, GNP and technology based manufacturing. The base GNP growth per year is 80 USD.

Industrial Development

This sector contains and calculates the number of firms supplying risk capital and ratio of high tech exporting to low tech exporting.

Base: Number of Risk Cap. F: 5 High Tech: 8 % Low Tech: 78 %

Technology Improvement

This sector calculates level of National Innovation System (NIS) and National Technology Improvement in Turkey.

System Diagram of the simulation model constructed is given in Appendix-B.

The dynamic organizing principle that is the core of the simulation model is stock/ flow/converter-based structure.

During the building of simulation model technology improvement dynamic model, stocks, flows and converters aggregated into largest possible sector. The sectors are representing by using process frames.

The most important accumulations of the system diagram are the NIS and Technology Improvement.

Other major stocks, flows and converters with their full descriptions used within the sectors of the simulation model can be listed as below.

Stocks:

econ G N P: Gross National Product of Turkey

edu level: Education Level ages 25-64 and high school or above

inward invest: inward investment

outward invest: outward investment

pop: population of Turkey

gov R&D: Government R&D expenditure

pri R&D: Private R&D expenditure

NIS: National Innovation System

Techno Impr: Technology Improvement in Turkey

gov R&D tVA: Government R&D expenditure based on technology value added

pri R&D tVA: Private R&D expenditure based on technology value added

tech GNP: GNP based on technology value added

accepted: Number of projects accepted by TUBITAK

proposed: Number of projects proposed to TUBITAK

article: Number of articles published by Turkish instructors in the abroad
instructors: Number of instructors in Turkey
num firm: Number of firms in USAM studies
Num USAM: Number of USAM

Rating Converters:

inc rate GNP: Increasing rate of GNP
edu level inc rate: Education level increasing rate
h tech exp: high technology export
l tech exp: low tech export
N of Risk f: Number of risk capital firms
inc rate iw: increasing rate of inward investment
inc rate ow: increasing rate of outward investment
inc rate pop: increasing rate of population in Turkey
inc rate g R&D: increasing rate of government R&D
inc rate pri R&D: increasing rate of private R&D
inc rate g R&D tVA: increasing rate of government R&D based on techno VA
inc rate pri R&D tVA: increasing rate of private R&D based on techno VA
tech GNP inc: rate of techno based GNP
inc tech manuf: increasing rate of technology based manufacturing
inc r acc: increasing rate of accepted projects by TUBITAK
inc r pro: increasing rate of proposed projects to TUBITAK
inc r art: increasing rate of number of articles published by Turkish instructors
inc r inst: incresing rate of instructors in Turkey
inc r firm: increasing rate of number of firms cooperating with USAMs
inc r USAM: increasing rate of number of USAMs

Flows:

yrly GNP: Yearly GNP increase
yrly edu level: Yearly education level increase
yrly iinve : Yearly inward investment increase
yrly oinve : Yearly outward investment increase
yrly pop: Yearly population increase
yrly g R&D: Yearly government R&D expenditure increase
yrly pri R&D: Yearly private R&D expenditure increase

yrly g R&D tVA: Yearly government R&D expenditure increase based on techVA
yrly pri R&D tVA: Yearly private R&D expenditure increase based on techVA
yrly tech GNP: Yearly technology based GNP increase
yrly acc: Yearly accepted projects by TUBITAK
yrly pro: Yearly proposed projects to TUBITAK
yrly art: Yearly articles published increase
yrly inst: Yearly instructors increase
yrly firm: Yearly firms in USAM cooperation increase
yrly USAM: Yearly USAM increase

Graphical functions have been used to represent trends and increasing rate of the entities within the simulation model. The model became simulatable model after the formulation and numeration of the elements of the technology improvement model. Simulation model built for the technology improvement policy is given in Appendix-C.

After the construction of the simulation model of national technology improvement of Turkey, the model was run with different policy options. The model was run for the period 2000-2014. It must be noted that real figures were used as much as possible. There are 5 scenarios for the analysis of different technology improvement policy of Turkey. The outputs of the runs were evaluated accordingly.
Scenarios applied to the simulation model are given below.

a) Scenario 1: Base run
b) Scenario 2: Increase number of risk capital firms, high/low technology export ratio and increase private R&D
c) Scenario 3: Increase number of firms in USAM cooperation, article/instructor ratio and education level
d) Scenario 4: Increase technology value added effect
e) Scenario 5: Increase outward investment and decrease inward investment

a) Scenario 1 : Base Run

The base run is performed without any policy suggestion in the future. The purpose of this run is to evaluate the trend and model outputs and to compare the trend with the reference behavior model.

The resultant graph can be seen in Figure 7-2.

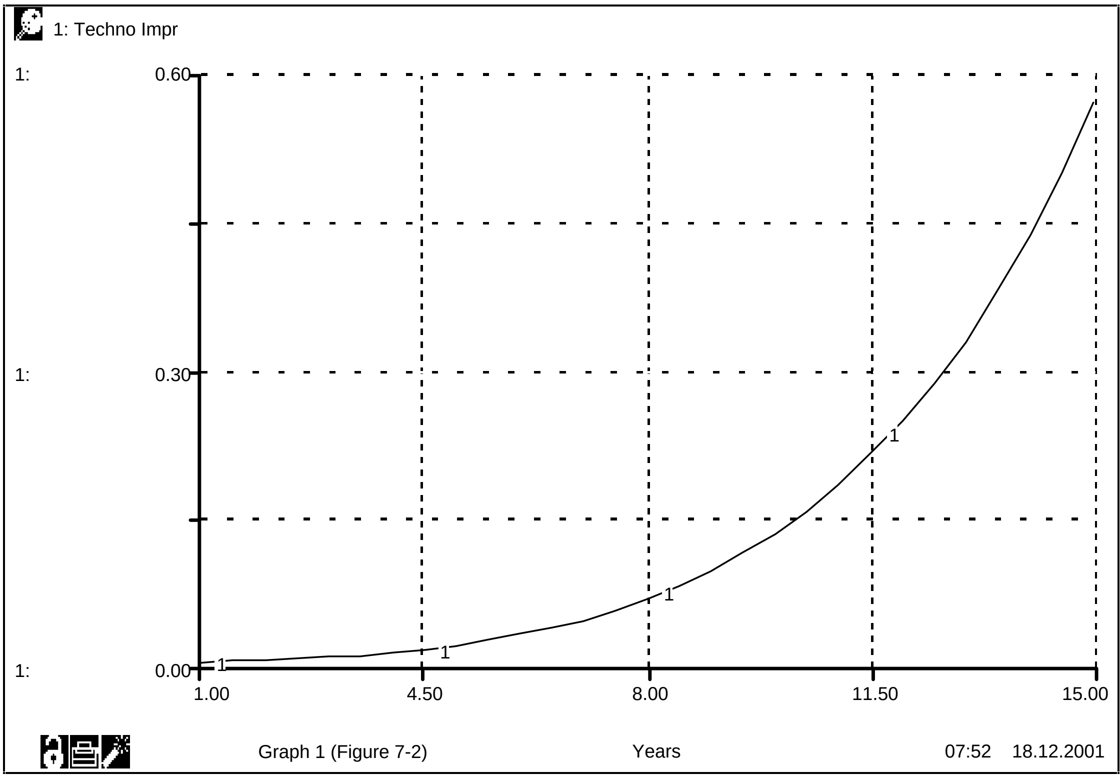

Figure 7-2: Scenario-1: BASE RUN

b) Scenario 2 : Increase number of risk capital firms, high / low technology export ratio and private R&D

Currently there are five risk capital firms namely, İş Bank, Vakıf Bank, Türkiye Teknoloji Geliştirme Vakfı (TTGV), TUBITAK and KOSGEB. In the base model; every 3 years there is one more new risk capital firm establishment, current high technology export percentage of Turkey was about 8% and gradually increases 4% and private R&D investment increase is 5%. According to scenario there will be one more new risk capital firm establishment every year, the high technology export percentage will be increased 5% and the private R&D investment increasing rate will be 20%.

Turkey has very few number of risk capital firms and also their budgets are very limited. Especially in the USA and EU there is very huge amount of risk capital investment. In the USA the risk capital investment is about 9.5 Billion USD (1996) and it is 6.7 Billion USD (1996) for EU (Erol Taymaz, 2001). Currently both high technology export and private R&D percentages are low in Turkey. The figures in industrialized countries are around 60-70% and 50-70% respectively.

As number of risk capital firms, high / low technology export ratio and private R&D expenditure values are increasing, the technology improvement is achieved. Especially there is an upward trend on technology improvement after 11th year.

The resultant graphs can be seen in Figure 7-3 and 7-4.

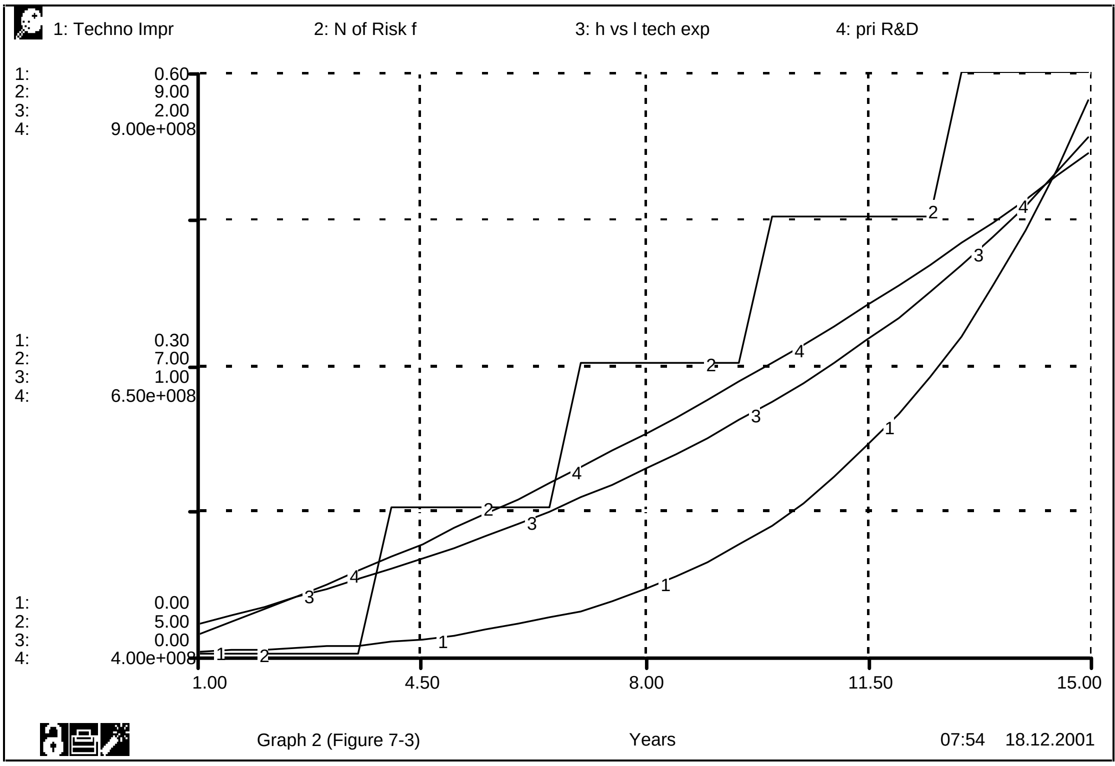

Figure 7-3: Scenario-2: 1st Status

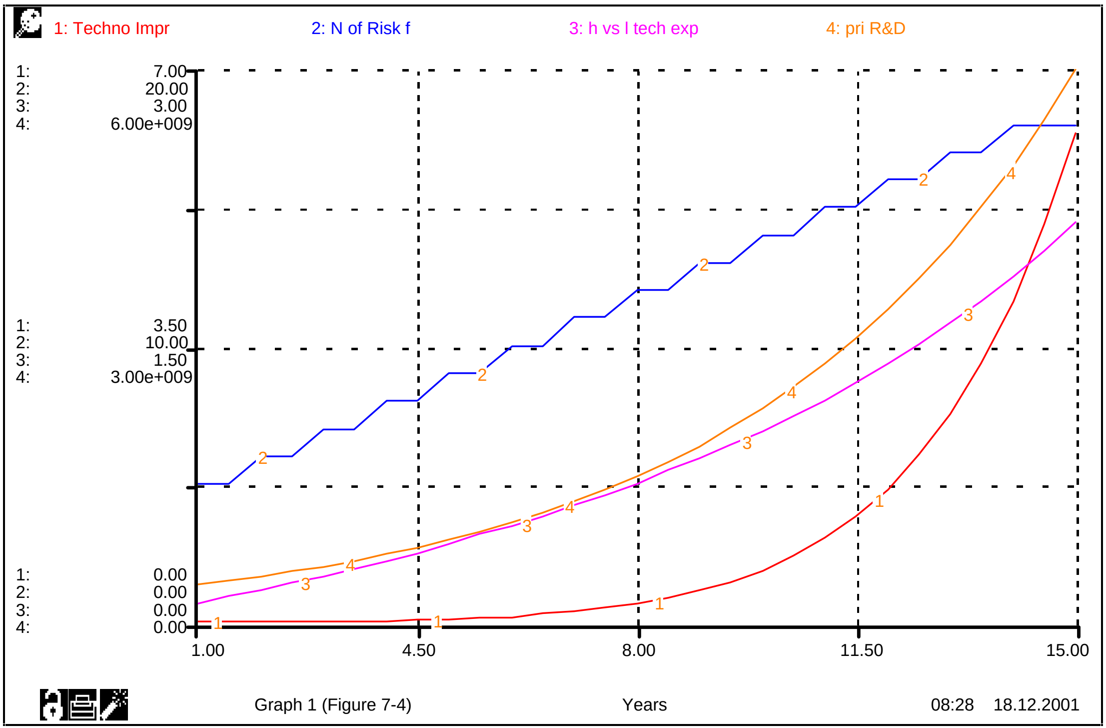

Figure 7-4: Scenario-2: Final Status

c) **Scenario 3 : Increase number of firms cooperating with USAM, article/instructor ratio and education level**

Currently there are 121 firms cooperating with USAM, there are 4742 articles published and 22001 instructors in Turkey. They are increasing 12%, 16% and 8% every year respectively. Education level is increasing 2% per year gradually. According to scenario, new percentages will be 20%, 30% & 10% respectively and education level will increase 4% per year gradually.

Under the scope of NIS, there is extensive cooperation between industry and the universities. In Turkey this relationship is very weak due to lack of information about it, heavy bureaucracy and has no qualified personnel for coordination (Erol Taymaz, 2001). Article / instructor ratio & percentage of high school, university graduates between 25-64 ages is very low when we compare them with the figures in industrialized countries.

As number of firms cooperating with USAM, article/instructor ratio and education level are increasing, the technology improvement is achieved.

The resultant graphs can be seen in Figure 7-5 and 7.6.

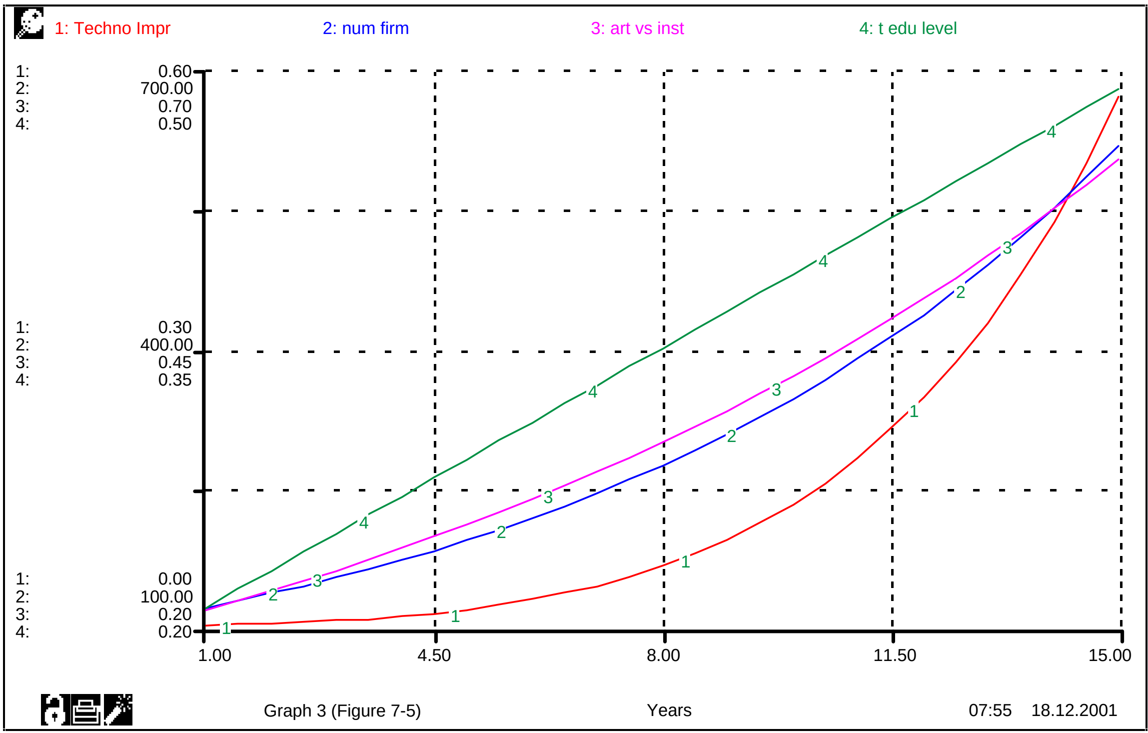

Figure 7-5: Scenario-3: 1st Status

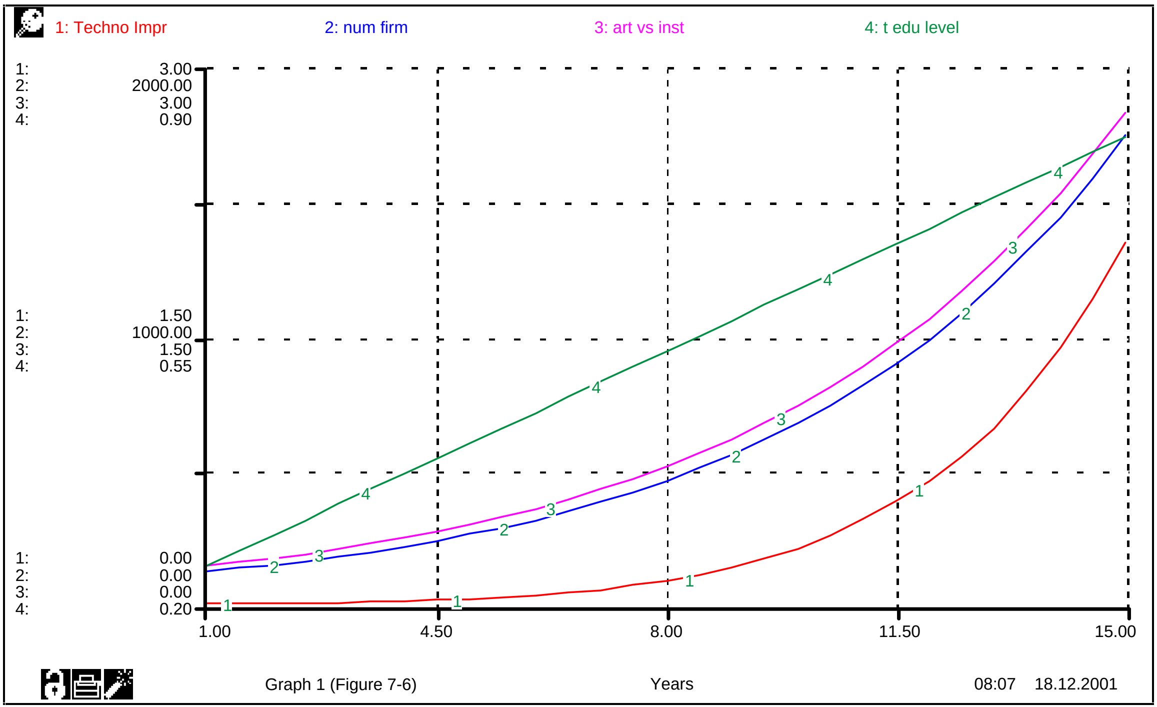

Figure 7-6: Scenario-3: Final Status

d) Scenario 4 : Increase technology value added effect

Currently government R&D expenditure is around 624 million USD and private R&D expenditure is around 416 million USD. They are increasing 5% per year. Mid of 1980s until the beginning of 1990s, there were remarkable technology investments. During these years the real GNP growth was about 2%-%3 which means that technology effect on per GNP increase was 80 USD / person. Thus at the base model 80 USD has been taken as technology VA GNP increase. According to scenario there will be extensive R&D and technology investment thus the government R&D will increase 20%, private R&D will increase 30% and technology effect on per GNP increase will be 400 USD.

Current R&D expenditure is very low in Turkey when we compare the figure with industrialized countries. Total R&D expenditure in Turkey (1.1 Billion USD: 1997) is even lower than the R&D expenditure of General Electric (1.5 Billion USD: 1997), which has the lowest R%D value in the list of the firms that have highest R&D expenditure. The effect of technology on GNP increase in Turkey is also very low. Korean R&D expenditure / GNP is 2.9% (1997), in Turkey it value is %0.5 which is very low. In addition Korean GNP per capita increased 400 USD on average.

As both private and government R&D expenditure and technology effect on GNP increase, the technology improvement is achieved.

The resultant graphs can be seen in Figure 7-7 and 7-8.

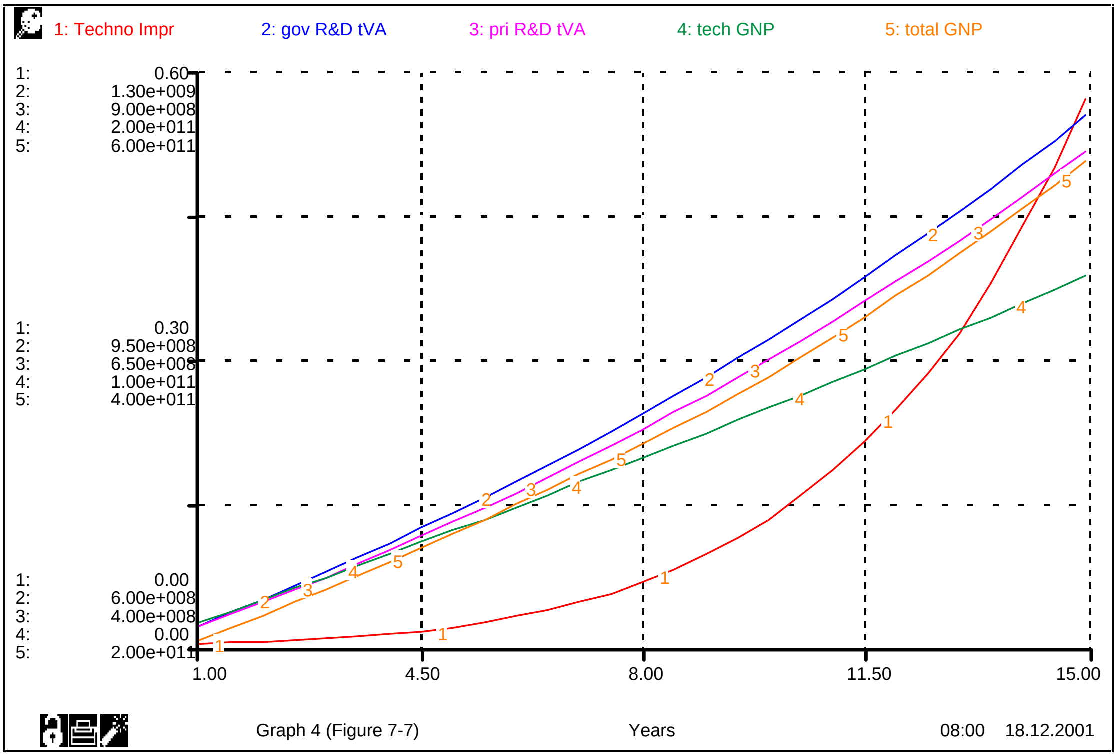

Figure 7-7: Scenario-4: 1st Status

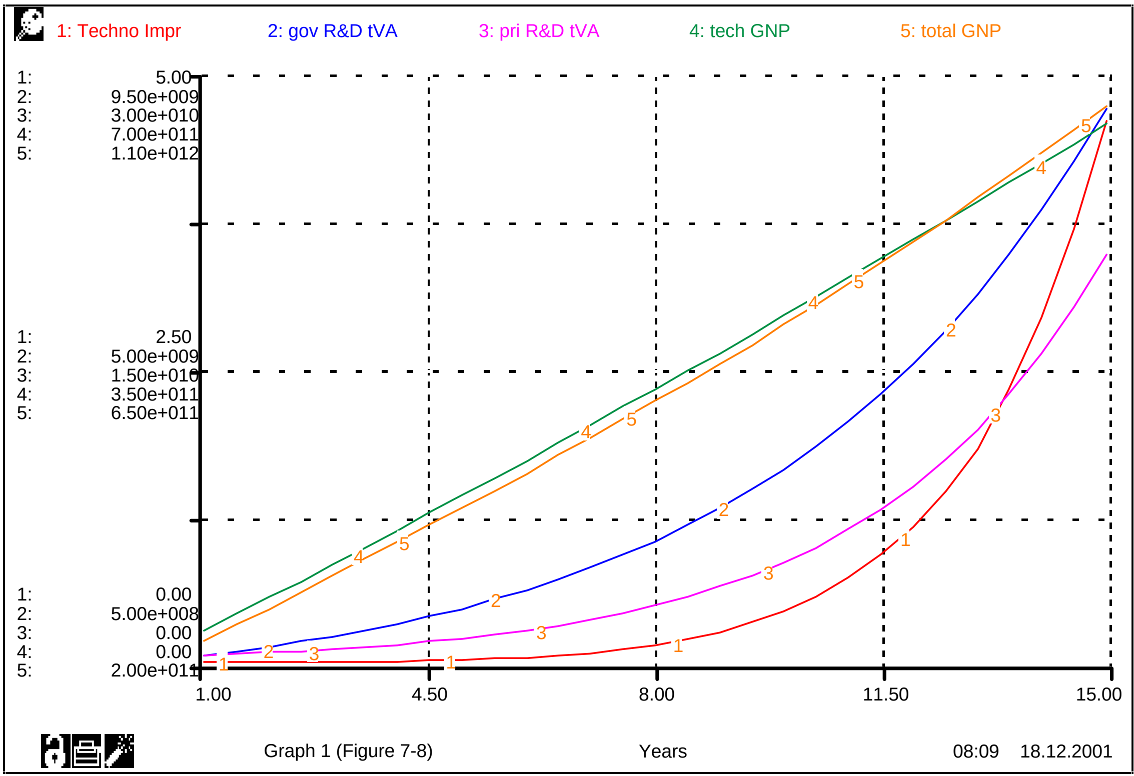

Figure 7-8: Scenario-4: Final Status

e) **Scenario 5 : Increase outward investment and decrease inward investment**

Currently outward investment is 775 Million USD and inward investment is 3.05 Billion USD. They are gradually increasing 5% every year. According to scenario outward investment is increasing 25% and inward investment is decreasing 20% every year.

In Turkey one of the main reasons of economical crisis is the unstable inward investment in Turkey. As the economical conditions get unstable even Turkish industry is investing in abroad such as in Romania, Bulgaria, Turkish Independent States and Russia. Turkey should get enough inward investment and should reduce outward investments in order to sustain a remarkable technology improvement.

As the inward investment increases and the ratio of inward / outward investment does not increase, technology improvement is achieved.

The resultant graphs can be seen in Figure 7-9 and 7-10.

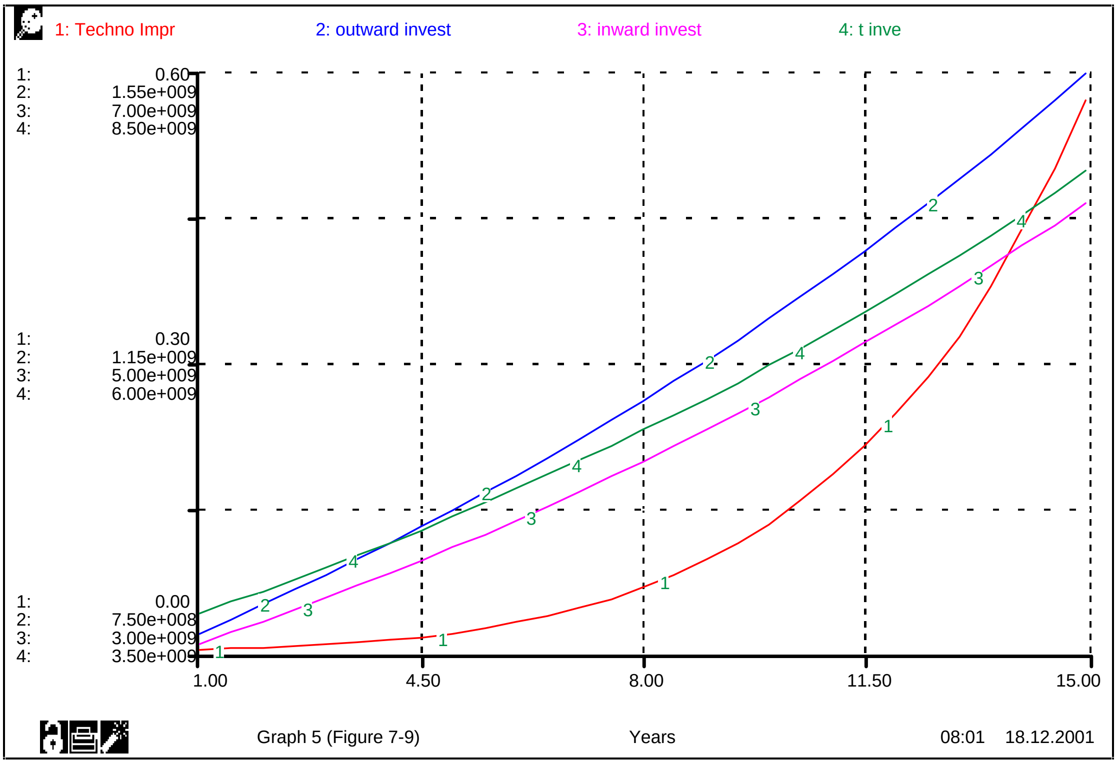

Figure 7-9: Scenario-5: 1st Status

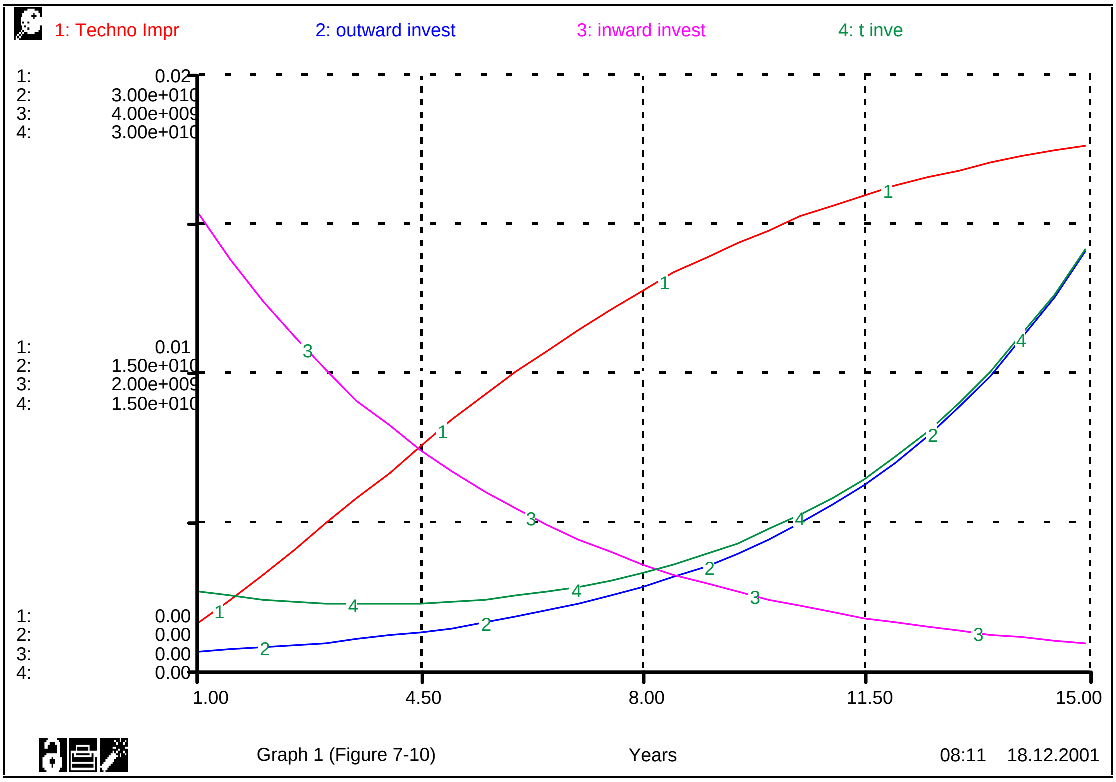

Figure 7-10: Scenario-5: Final Status

8. VALIDITY OF THE MODEL

Structural Validity

All the entities, feedback loops, concentration areas and the equations had been identified by expert opinions and checked with literature. Thus structural validation is achieved.

Behavioral Validity

The model produces stable data and there is no non-normal output. Thus behavioral validation is achieved.

Policy Validity

The model responds to policy changes as expected. Thus policy validation is achieved.

Mechanical Mistake Test

There is no unexpected negative sign, question mark sign, or infinity sign in the outputs. Thus the model passed the mechanical mistake test.

Passed Robustness Test

First each sector is simulated in isolation individually then group of sectors and finally whole model are simulated. Thus model passed robustness test.

Reference Behavior Pattern Test

The outputs are very similar to reference behavior pattern. Thus the model passed the reference behavior pattern test.

In conclusion, the model is valid by considering the facts discussed above.

9. CONCLUSION

The aim of this study was to show that system dynamics methodology is a proper and valid tool on national policy analysis for technology improvement. The results obtained are positive. The model seems to be applicable to real life.

As there are plenty of social, economical and technical parameters related with technology improvement activities, the abstractions made during the construction of the model may result in some inconsistencies. They can be corrected by more extensive analysis, adjustment of parameters and employing other research techniques which necessitates more time than a dissertation term allows and a research team rather than one graduate student only.

But in spite of all above existing difficulties, this article shows that System Dynamics methodology is proven to be a competent technique for technology improvement policy analysis and after more precise adjustments of the parameters, the system model representing national technology improvement can be used by policymakers.

In order to achieve national technology improvement in Turkey, number of risk capital firms, high / low technology export ratio, number of firms cooperating with USAMs, number of USAMs, article/instructor ratio, education level, both private and government R&D expenditures, technology effect on GNP, inward investment should be increased and the ratio of inward/outward investment should not be fluctuated/decreased.

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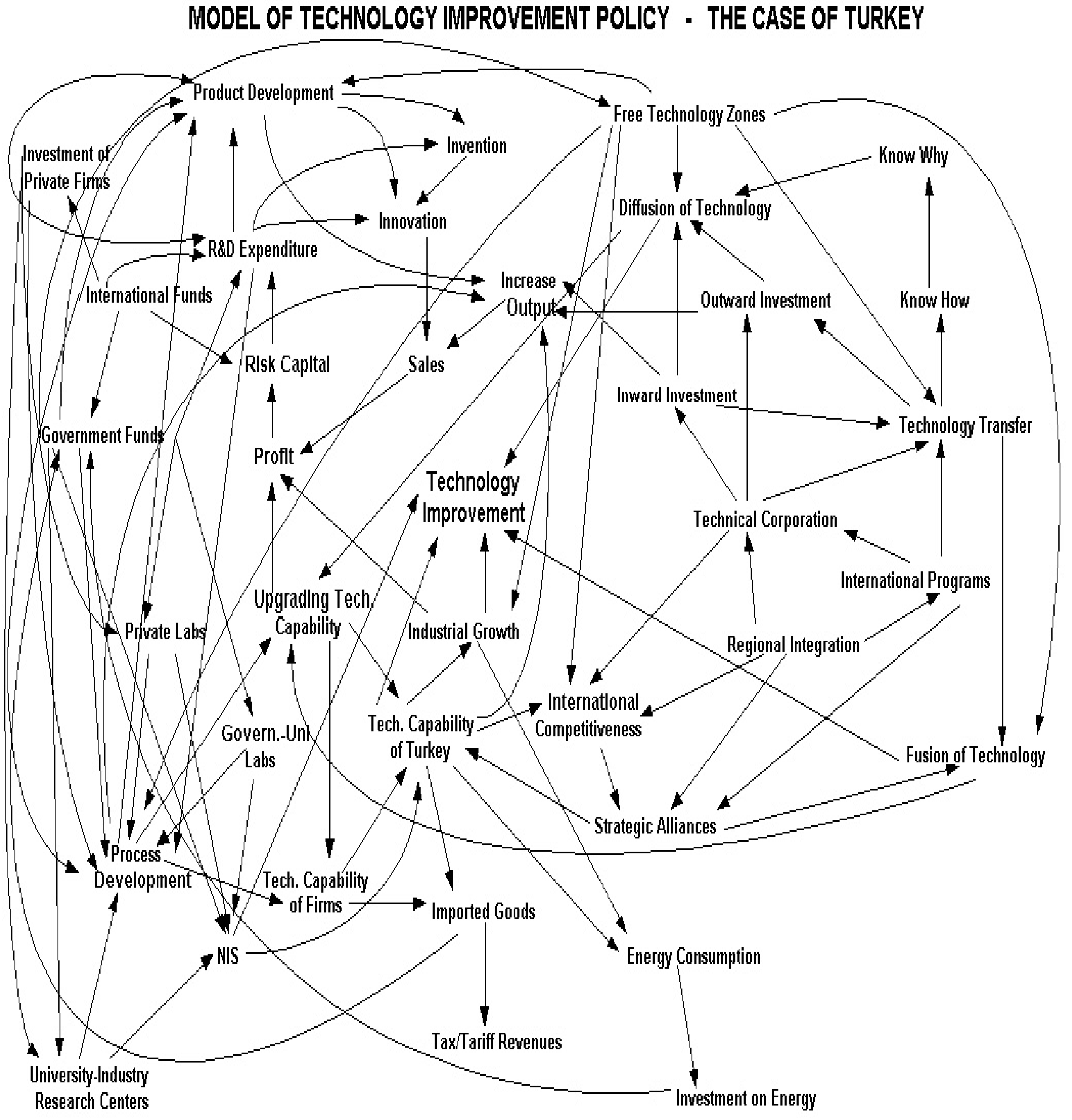
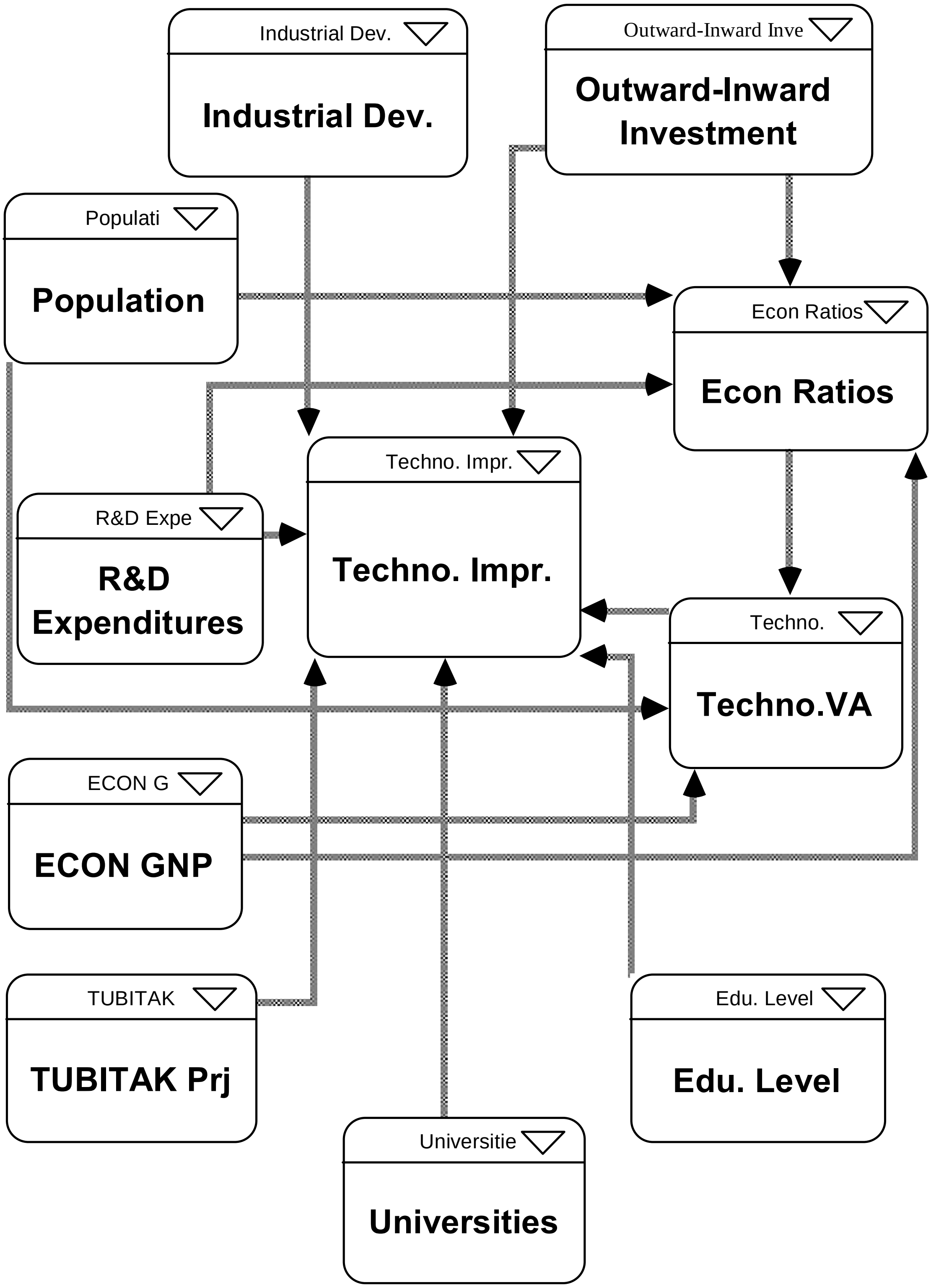
APPENDIX – A
INFLUENCE DIAGRAM



APPENDIX - B
SYSTEM DIAGRAM OF THE MODEL



APPENDIX - C SIMULATION MODEL