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Khan, Haider

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Haider A. Khan*

Professor of Economics
Graduate School of International Studies
University of Denver
Denver, Co. 80208, U.S.A.
e-mail address: hkhan@du.edu
fax: 301-871-2456

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Abstract

This paper presents a somewhat novel theory of innovation in the economy wide setting. The starting point for this theory is the creative destruction process at the firm and industry level. However, an extension to an economy wide setting requires the explicit theorization of the role of the state as well as an interacting nonlinear market process. The direction in which the theory leads is a complex interaction between state policies and market processes that influence the decisions taken by specific firms in particular areas of innovative activities. The key concept that is developed in this context can be called a *Managed Creative Destruction*(MCD) process. In a national (or regional) MCD, the creative destruction process characterizing innovation is structured more consciously by the state (or the states in a particular region). It can be argued that China is now going through this process. In this paper the particular case studied is South Korea's recent historical experience. Following Schumpeter we assume that innovation in specific firms can have economy-wide effects. Models based on this idea can be shown to have multiple equilibria. The idea of a positive feedback loop innovation system or POLIS is formalized by picking an appropriate sequence of equilibria over time. It is shown that POLIS has empirical relevance by applying the formal model to an actual economy. Recent financial crisis in many Asian countries, most notably South Korea, seems to have reversed the conventional wisdom regarding the East Asian "miracle". This paper applies the concept of a POLIS to show that neither the current view that the miracle was a mirage nor the earlier contrarian view that the growth was a result of factor accumulation only is correct. Ultimately technological transformation — in particular the creation of a positive feedback loop innovation system is what makes the difference between sustained growth and gradual or sudden decline. Although various problems remain in both the real and the financial sectors, it will be premature to dismiss the impressive achievements and the future possibilities of the South Korean economy.

Keywords: technological transformation, multiple equilibria, POLIS (positive feedback loop innovation system), Korea,South Korean POLIS, Managed Creative Destruction(MCD)

JEL Categories: O33, D50, D57, O38

1. Introduction

This paper presents a somewhat novel theory of innovation in the economy wide setting. The starting point for this theory is the creative destruction process at the firm and industry level. However, an extension to an economy wide setting requires the explicit theorization of the role of the state as well as an interacting nonlinear market process. The direction in which the theory leads is a complex interaction between state policies and market processes that influence the decisions taken by specific firms in particular areas of innovative activities. The key concept that is developed in this context can be called a *Managed Creative Destruction*(MCD). In a national (or regional) MCD, the creative destruction process characterizing innovation is structured more consciously by the state (or the states in a particular region). It can be argued that China is now going through this process. In this paper the particular case studied is South Korea.[1] Using recent economic history the process of MCD in this particular case is studied in detail so that the somewhat abstract features of the theory and the mathematical modeling of the theory can be seen in a concrete context.

In Capitalism, Socialism, Democracy Schumpeter characterized creative destruction in the following way:

> The fundamental impulse that sets and keeps the capitalist engine in motion comes from the new consumers' goods, the new methods of production or transportation, the new markets,.... (This process) incessantly revolutionizes the economic structure *from within*, incessantly destroying the old one, incessantly creating a new one. This process of Creative Destruction is the essential fact about capitalism.[2]

The essence of capitalism in this view, is the constant revolutionizing of the economic structure from within. Marx had made a similar observation about the endogenous nature of technical change (Marx, 1867, 1945). Recently Aghion and Howitt (1992) have proposed a model of creative destruction by treating the innovation process as in the patent-race literature.

The present paper assumes following Schumpeter and Aghion and Howitt that innovation in specific firms can have economy-wide effects. The expected growth rate of the economy depends on the economy-wide amount of research; but the process of this growth, precisely because research leads to the development of new products and processes, is characterized by creative destruction.

[1] The complexities of this MCD process at the country level can not be overemphasized. Even after emabarking on the process crises could set it back as Khan(2004) shows. For an excellent discussion of some further problems in post-crisis Korea see Lee et.als.(2005)

[2] Schumpeter (1942) p. 83

The relationship between R&D and growth is therefore both intimate and complex. An economy-wide model intending to capture this complex relationship will need to posit non-linearities and complex feedback rules. In this paper, an attempt is made by endowing production functions and correspondences with some of these features. In particular, by defining non-linear production structures so that increasing returns and endogenous innovations are possible one can explore the properties of fixed points that define equilibria at any point in time. A sequence of such equilibria over time, picked by an appropriate selection procedure, can then show the evolution of the system.

Section 2 presents the idea of technological complexity which leads to MCD and two relevant models motivated by this discussion. The existence and characterization of multiple equilibria show the possibility of creating a positive feedback loop innovation system (POLIS) in a model economy on an abstract function space. Section 3 is an initial attempt to apply the abstract theorems to a real world economy through a series of linear approximations. The economy chosen for this purpose is that of South Korea. Recent controversy between contending perspectives on technological change makes Korea an interesting case. Potentially, a modeling approach embodying POLIS offers an alternative to the standard growth accounting approach to assessing the presence and impact of technical change. The results presented here are preliminary but promising enough to establish the empirical relevance of the alternative models of growth through creative destruction.

2. Technological Complexity and Models of POLIS

2.A. Technological Systems as Complex Structures

As the debate on the "East Asian miracle" underlines, the key strategic question for a country that has made a technological transition from a traditional to a modern system concerns the prospects for long-term economic growth. Ultimately, it is the sustainable long-term rate of growth that will determine the wealth that can be distributed among personal consumption, investment, government spending on infrastructure and public services, etc.

Therefore, it is the creation of an innovation system that will determine the viability of a technology-based growth process. This process of building an innovation system is very much an evolutionary and path-dependent process.(Nelson 1981, 1989, 1993, 1994; Nelson and Winter 1974, 1977, 1982) The central idea is that the provision of appropriate types of capital, labor and forms of organization for high value-added industries will lead to rapid productivity increases. However, to sustain such an increase, a domestic innovation system must be set up. There is a further requirement that this innovation system must fulfill. This is the requirement of a positive feedback loop or a virtuous cycle of innovations.

This problem, as we will see soon, is intimately connected with the existence of multiple equilibria in complex economies. A positive feedback loop leading to a virtuous cycle of growth and technology development is one particular sequence of equilibria in this context. In general, such a sequence also involves increasing returns. In the remainder of this section a theoretical exploration of innovation with increasing returns and multiple equilibria will be undertaken.

In a market economy, 'success' is often cumulative or self-reinforcing. Typically outcomes are not predictable in advance. However, once an equilibrium gets selected out of a number of long-run equilibria, there is a tendency to be locked in. Technically, economic processes exhibit non-convexities -- violating the generic assumption of competitive equilibrium economics. The presence of self-reinforcing mechanisms sharing common features found in fields as far apart as enzyme reactions and the economics of technical change underlines the importance of such mechanisms in governing the dynamics of self-reinforcing processes regardless of the field in which they occur.

2.B. A 'Simple' Non-linear Model of Complexity[3]

In order to give the reader some idea of the problem of formalizing complex technological systems I summarize here the basic structure of a 'simple' non-linear model embodying distinct technological systems. At any single point in time, the model can be presented as a Social Accounting Matrix (SAM) representation of the socio-economic system. The key distinction here is the explicitly non-linear nature of the economy-wide functional relationships. The key theorem shows the existence of multiple equilibria. Some further considerations of complexity and increasing returns show that multiple equilibria are indeed the natural outcomes in such models. Thus, there would seem to be some role for domestic policy in guiding the economy to a particular equilibrium among many.

The virtue of an economy-wide approach to technology systems is the embodiment of various inter-sectoral linkages. In a SAM, such linkages are mappings from one set of accounts to another. In terms of technology systems, the production activities can be broken down into a production (sub-) system and a set of innovative activities. In practice, this presents considerable difficulties of classification and empirical estimation.

One major component of the entire innovation system is, of course, the expenditures on R&D. In the SAM for Korea used here, this can appear either as an aggregate expenditure along the column labeled R&D, or as a set of disaggregated

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[3] Khan (1997c ,1998,2002 and 2004) contain technical discussion and proofs of Existence of multiple equilibria for an entire class of models of this type.

expenditures.[4] In the latter case these may be specified according to productive activities (e.g., construction, electrical equipment, etc.) or by institutions (e.g., private R&D expenditures, government R&D expenditures, etc.). It should be emphasized that the dynamic effects of R&D on the economy can be captured only in a series of such SAMs over time. This approach is still at the conceptual stage, but appears to be quite appealing. One can contrast the possible policy experiments that can be undertaken within such a framework with the apparently ad hoc science and technology policies in many developing countries. In particular, the impact over time of a POLIS can be traced by building and maintaining such SAMs.

Choice of new technology in a developing country is affected by research and development in at least three different ways. Such a country can attempt to develop new technology through R&D, as mentioned previously. This ultimately requires a positive feedback loop innovation system in order to be self-sustaining. Another alternative is to adapt existing technology. This too requires a production system geared towards innovation in a limited way. A third alternative is to import technology or to acquire it through attracting foreign direct investment. In practice, all these different forms may be combined. The abstract model embodies all these different possibilities. However, the first option requires, among other things, a presence of multiple equilibria.[5] In a unique equilibrium world the competitive equilibrium (under the assumption of complete markets) will always be the most efficient one. The presence of increasing returns usually destroys such competitive conditions.

We begin with a number of productive activities reflecting the existing technological structure. This activities are defined on the input-output subspace of the general and abstract mathematical space X. In addition to the values of inputs and outputs, points in this space could also represent household and other institutional income and expenditure accounts. We also incorporate the possibility of R&D as a separate productive activity. Formally, it is always possible to break R&D down into as many finite components as we want. The key relationship in this context is that between the endogenous accounts (usually, production activities and technologies, factors and households) and the exogenous ones. It is this relationship that is posited to be non-linear and this together with some assumptions on the relevant mathematical space can lead to the existence of multiple equilibria.

Although the existence theorems for these multisectoral models provide some structure for the equilibria as sequences of fixed points in the socio-economic structure with evolving technology systems, it is not specified a priori which equilibrium will be reached. The problem of equilibrium selection thus remains open. The idea behind a POLIS can now be stated somewhat more formally. It is to reach a sequence of

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4 Both types of specifications are possible in principle. In practice, as in the case of South Korea, the availability of data will often determine what type of specification will be used.

5 This could be considered a modern mathematical representation of Schumpeter's idea that perfectly competitive firms were singularly unmotivated to innovate.

equilibria so that in the non-linear models of the entire economy the maximal fixed points that are attainable are in fact reached through a combination of market forces and policy maneuvers over time. It is also to be understood that path-dependence of technology would rule out certain equilibria in the future. Thus initial choices of technologies can matter crucially at times.

2. C. The Model on a Lattice

Define X as a vector lattice over a subring M of the real field R.

Let $x_+ = \{x \mid x \in X, x \geq 0\}$

A non-linear mapping N is defined such that $N : X_+ \to X_+, N_0 = 0$. Given a vector of exogenous variables d, the following non-linear mapping describes a simultaneous non-linear equations model of an economy, E:

$x = Nx + d$

(1)

for a given $d \in X_+$.

This non-linear system represents a socio-economic system of the type described previously. In order to specify the model further, the following assumptions are necessary.

1. X is order complete
2. N is an isotone mapping
3. $\exists \hat{x} \in$ such that $\hat{x} \geq N\hat{x} + d$

In terms of the economics of the model, the non-linear mapping from the space of inputs to the space of the outputs allows for non-constant returns to scale and technical progress over time. The 3 assumptions are minimally necessary for the existence of an equilibrium. Assumption 3, in particular ensures that there is some level of output vector which can be produced given the technical production conditions and demand structure.

Existence of Multiple Equilibria:

Theorem: Under the assumptions 1 - 3, there exists $x^* \in X_+$ so that x^* is a solution of $x = Nx + d$

Proof: Consider the interval $[0, x] = \{\hat{x} \mid \hat{x} \in X_+, 0 \leq \hat{x} \leq x\}$ where $\hat{x}$ is defined as in assumption 3. Take a mapping F.

$F : x \in X_+ \to Nx + d$

F is isotone and maps $[0, x]$ into itself.

Define a set $D \equiv \{x \mid x \in [0, x], x \geq Fx\}$.

By assumption 3, D is non-empty.

We now show $x^* \equiv \inf D$ is a solution to $x = Nx + d$. $x^* \equiv \inf D$; therefore $x^* \leq x, \forall x \in D$. F is isotone; therefore $Fx^* \leq Fx \leq x$ for each $x \in D$ implying.

$Fx^* \leq x^*$

From (2) we have $F(Fx^*) \leq Fx^*$. Thus $Fx^* \in D$; hence $x^* \equiv \inf D \leq Fx^*$ so, $Fx^* \leq x^* \leq Fx^*$. Therefore $x^* = Fx^*$.

This is an application of Tarski's and Birkhoff's theorem. The key feature to note here is that the equilibrium is not necessarily unique. It should also be noted that under additional assumptions on space X and the mapping N the computation of a fixed point can be done by standard methods (e.g. Ortega and Rheinboldt).

2.D. *Multiple Equilibria on Banach Space:*

In this section the results for multiple equilibria are extended to functionals on Banach Space. We can define the model again for monotone iterations, this time on a non-empty subset of an ordered Banach space X. The mapping $f : X \rightarrow X$ is called compact if it is continuous and if $f(x)$ is relatively compact. The map f is called completely continuous if f is continuous and maps bounded subsets of X into compact sets. Let X be a non-empty subset of some ordered set Y. A fixed point x of a map $N : X \rightarrow X$ is called minimal (maximal) if every fixed point y of N in X satisfies

$x \leq y (y \leq x)$

Theorem: Let (E, P) be an ordered Banach space and let D be a subset of E. Suppose that $f : D \rightarrow E$ is an increasing map which is compact on every order interval in D. If there exist $y,\ \hat{y} \in D$ with $y \leq \hat{y}$ such that $y \leq f(y)$ and $f(\hat{y}) \leq \hat{y}$, then f has a minimal fixed point x. Moreover, $x \leq y$ and $x = \lim F^k(y)$. That is, the minimal fixed point can be computed iteratively by means of the iteration scheme

$$x_0 = y$$

$$x_{k+1} = f(x_k) \qquad k = 0,1,2,....$$

Moreover, the sequence (x_k) is increasing.

Proof: Since f is increasing, the hypotheses imply that f maps the order interval $[\bar{y}, y]$ into itself. Consequently, the sequence (x_k) is well-defined and, since it is contained in $f[\bar{y}, y]$, it is relatively compact. Hence it has at least one limit point. By induction, it is easily seen that the sequence (x_k) is increasing. This implies that it has exactly one limit point $\bar{x}$ and that the whole sequence converges to $\bar{x}$. Since f is continuous, $\bar{x}$ is a fixed point of f. If x is an arbitrary fixed point in D such that $x \geq \bar{y}$, then, by replacing y by x in the above argument, it follows that $\bar{x} \leq x$. Hence $\bar{x}$ is the minimal fixed point of f in $(\bar{y} + P) \cap D$. It should be observed that we do not claim that there exists a minimal fixed point of f in D.

We can also show that if $F : x \in X_+ \rightarrow Nx + d$ is an intersecting compact map in a non-empty order interval $[x, \hat{x}]$ and $x \leq Fx$ and $F\hat{x} \leq \hat{x}$ then F has a minimal fixed point x^* and a maximal fixed point x^{**}. Moreover, $x^* = \lim F^k(x)$ and $x^{**} = \lim F^k(\hat{x})$. The first of the above sequences is increasing and the second is decreasing.[6]

2.E. Translating the Non-linear Model

[6] See Amann (1976) for a 'constructive' proof.

These models, interpreted with due caution, demonstrate the theoretical possibility for a (Schumpeterian) positive feedback loop innovation system. However, it is far from transparent how such a system can be represented in actuality. In the next section, an attempt will be made to first define precisely what technological systems are from an empirical standpoint for a specific NIE such as South Korea or Taiwan. Based on this, an operational way of capturing such systems empirically will be presented. The vehicle chosen for such a representation is the Social Accounting Matrix or SAM. SAMs are elaborate quantitative constructions based on social and economic data that can show the economy at a point in time with the necessary detail. How do we depict different technology systems in a SAM? How can we show the evolution of a technology system in such a construction? How do we incorporate R&D and other factors of significance in understanding innovation in a SAM? These are some of the questions we need to raise. At the end, through a series of approximations the non-linearities and complexities of an innovation system can be approached meaningfully by using empirical SAMs for particular countries.[7]

[7] Khan (1997c, and 1998, forthcoming) offer a technical description of the exact empirical methods and computational details.

3. Korea: The Making of a POLIS? An Economic History and Modeling based on Social Accounting Matrices

The purpose of this section is to answer the question: has Korea succeeded in constructing a positive feedback loop innovation system? After the theoretical discussion in the previous section the importance of this question is obvious. However, strategies for finding the answer are less transparent.

The discussion in the previous section calls for disaggregated analysis; but it is not clear a priori what the appropriate level of disaggregation should be. Both microlevel evidence and macroeconomic connections need to be taken into account. Data limitations also inhibit detailed inquiry. Keeping this in mind, we will nevertheless try to explore both microeconomic factors at the firm level and connections among different sectors. Needless to say, research and development will be an important area of investigation.

3. A. The Development of Modern Technology in Korea

Whatever the record in the 1960s and 1970s, by the 1980s Korea did enter a largely modern technology-centered era (Amsden, 1989; Khan, 1997a; Pack, 1987, 1992, 1994; Pack and Page, 1994a, 1994b; Pack and Westphal 1986; Westphal, 1990). Therefore, we need to investigate the situation during the last decade and a half in order to see the source and role of this modern technology system. First, it is necessary to look at the transfer of technology from abroad to Korea. In the process we also will have an opportunity to examine Teitel's characterization of the three phases of technological development. According to Teitel (1984 a, b) the first phase is the acquisition of technology from abroad; the second phase involves the modification of borrowed technology. The final phase is the generation of technology at home. This acquisition-modification-creation process can be observed in the history of economic evolution of the advanced industrial countries.

The government of Korea passed the Technology Development Promotion Act (TDPA) in 1972 the purpose of which was to facilitate technology imports. This coincided with the establishment of Technology Imports Counseling Center at the Korea Institute of Science and Technology. At the same time the Korea Development Bank's 'technology development fund' originated as a source of financing. The following year the TDPA was further liberalized to relax the approval criteria for imported technologies.

The third and fourth five-year economic development plans emphasized the role of heavy and chemical industries. A form of industrial policy can be seen to be at work here. Table 1 summarizes the changes in Technology import policy since 1978. The financial assistance facilities also played important roles. These are presented in table 2. Table 3 shows the declared industrialization and technology strategies during the decade of 1960s, 1970s and 1980s. It is important to note that promotion of high-tech industries became a goal only in the 1980s.

Table 1: **Changes in Technology Import Policy since 1978**

Period	**Contents**	**Industry**
First Step (April 1978)	- Automatic approval items: • advance payment less than $30,000, royalty rates less than 3%,license period less than 3 years • Total royalty less than $100,000	Machinery, shipbuilding, electrical goods, electronics, fabricated metal products, chemicals, textiles.
Second Step (April 1979)	- Automatic approval items: • Advance payment less than $50,000, royalty rate less than 10%, license period less than 10 years	All industries, except nuclear energy and defense industry.
Third Step (July 1980)	- Automatic approval items: royalty rate less 10%, license period less than 10 years	All industries.
Fourth Step (September 1982)	- Delegation of approval authority to the competent ministry	All industries.
Fifth Step (July 1984)	- Transition from the approval system to a reporting system	All industries.
Sixth Step (July 1986)	- Transfer of trademarks only permitted	All industries.
Seventh Step (July 1988)	- Delegation of approval authority to Class A foreign exchange banks under the Foreign Exchange Control Act, except in cases where the license period exceeds 3 years and the total royalty exceeds $100,000 or the royalty rate exceeds 2% (or initial payment exceeds $50,000)	All industries.

Source: Korea Industrial Technology Association, Surveys on Technology Imports, 1992, p.9.

As Table 1 shows changes in technology import policy since 1978 have become more liberal. The openness that existed with respect to trade in consumer goods can be said to have been extended to capital goods with embodied technology. Table 2 shows the general structure of the financial assistance system. Clearly, without such financing, technology imports would be hampered. These policies are consistent with the general development strategies by stages of development as shown in Table 3.

Table 2: **Financial Assistance System**

Government Subsidy	Direct subsidy to private firms or industrial technology research association who participate in special R&D project or industrial basic technology development project for 40-80% of R&D fund.
Loan by Policy Fund	Annual 5.0-10.5% interest rate loan on R&D and

	commercialization of new technology.
General Loan	Loan assistance to R&D and commercialization of new technology by Korea Development Bank, Small-Medium Firm Bank, and other banks. The same interest rates as bank loans.
Assistance to Venture Capital	Korea General Technology Fund (Inc.)
Technology Credit Guarantee	Technology Credit Guarantee Fund

Source: KIET, Program for Technology Banking System Improvement, 1992.

Table 3: **Development strategies by stages of development**

Period	Direction of Industrialization	Technological development strategy
1960s	1. Establishment of the foundation for industrialization. 2. Fostering of import-substitution industries. 3. Expansion of export-oriented light industries (mainly labor-intensive industries).	1. Expanding education in science and technology and training in skills. 2. Establishment of the legal and institutional basis for the promotion of science and technology. 3. Facilitating the importation of advanced technologies.
1970s	4. Enhancing the sophistication of industries and fostering the heavy and chemical industries. 5. Promotion of small- and medium-sized industries. 6. Strengthening the competitiveness of industries in the international market.	1. Upgrading technological and scientific training in priority areas. 2. Facilitating the adaptation and improvement of imported technologies through the establishment of research entities in private industries. 3. Strengthening industrial technology research and development capability.
1980s	7. Enhancing the quality of export goods. 8. Promotion of skill-intensive industries (high-tech industries). 9. Fostering of information industry	1. Providing the large-scale recruitment from abroad and training of highly qualified scientific and technological manpower. 2. Liberalization of technology imports. 3. Preparation for an information-oriented society.

Source: Excerpted from Khan (1997a).

It is interesting to note that as the Korean economy has grown it has progressively imported more technology. More than 75 percent of all foreign technologies imported between 1962 and 1991 came from Japan and the U.S. Table 4 shows TI (technology imports), FDI (Foreign Direct Investment) and capital goods imports by Korea. The growth in imported technology and capital goods is noticeable throughout the 1980s.

Table 4: TI, FDI, and Capital Goods Imports: 1962-91

year	**TI payment (A, $million)**	**TI case**	**FDI• (B, $ million)**	**FDI• case**	**A/B (%)**	**Capital Goods Imports (C, $million)**	**C/total imports (%)**
62-66	0.8	33	47.4	39	1.7	486.0	18.9
67-71	20.4	285	218.6	350	9.3	2668.0	30.8
72-76	96.5	434	879.4	851	11.0	8106.0	27.3
77	58.1	168	83.6	54	69.5	3008.1	27.8
78	85.1	297	149.4	51	57.0	5080.3	33.9
79	93.9	291	191.3	55	49.1	6314.0	31.0
80	107.2	222	143.1	40	74.9	5125.0	23.0
81	107.1	247	153.1	44	70.0	6158.2	23.6
82	115.7	308	189.0	56	61.2	6232.7	25.7
83	149.5	362	269.4	75	55.5	7814.7	29.8
84	213.2	437	422.3	104	50.5	10106.3	33.0
85	295.5	454	532.1	127	55.4	11078.9	35.6
86	411.0	517	354.7	203	115.9	11340.2	35.9
87	523.7	637	1063.3	362	49.3	14552.4	35.5
88	676.3	751	1282.7	342	52.7	19033.4	36.7
89	888.6	763	1090.2	336	81.5	22370.3	36.4
90	1087.0	738	802.5	296	135.5	25451.3	36.4
91	1183.8	592	1396.0	287	84.8	30092.0	36.9
total	6109.3	7526	9268.8	3672	65.9	195016.0	33.3
ratio (%)	(3.1)		(4.8)			(100)	

- approval basis.

Sources: Korea Industrial Technology Association, Major Indicators of Industrial Technology, 1992; Ministry of Finance, The Status of Foreign Direct Investment, Dec. 1991; The Korean Statistical Association, Major Statistics of Korean Economy, 1992.

The adoption and diffusion of technology (imported or otherwise acquired), will inevitably require various lengths of time. On the demand side, the profitability of imported technology must be a major factor. However direct measures are impossible to get. A proxy (Khan 1997a) is obtained by considering the profitability of the large and medium sized enterprises which are assumed to use imported technology. Adaptabilities of technologies also matter. The extent to which imported technologies can be adapted to domestic needs and circumstances also depends mainly on the technological capabilities of the host firms. Here, too, the large- and medium- sized enterprises will generally have a better chance of adapting the foreign technology.

It is possible to construct the relevant information a SAM with Technology Systems (SAM-TECH) format. Looking at the information organized as a SAM-TECH as well as closely within its components results in the following observations:

1. With the exception of heavy industries, large and medium firms import relatively new technologies. This is consistent with Khan's (1997a) finding that the production functions in different firm sizes within the same industry differ.

2. Large size firms also seem to have greater bargaining power. They have shorter waiting periods for adoption of foreign technology.

3. Industries with competitive structures import technology at a slower rate than those which are oligopolistic.

4. In its acquisition, the price of new technology seems less of a determinant than the perceived needs of the firm. In other words demand for technology imports has been inelastic in many cases.

Given the prevalence of foreign technology in a number of sectors, one should expect more productivity increase in these sectors than in the other sectors with less than state-of-the-art technology. On the whole, this does turn out to be the case. However, the average for the foreign technology-intensive sectors turns out to be 2.8 percent TFP growth annually from 1980 to 1994.

If imported technology were the only source of technology for the modern technology system, then the question of whether Korea has a POLIS could be settled immediately. The short answer would be that indeed it has no POLIS. However, the policies of the Korean government and the efforts of large Korean firms to create a national innovation system cannot be passed over in silence.

3.B. Learning to Innovate: The Korean National Innovation System

Larry Westphal and Howard Pack among others, have emphasized the role of industrial policy in an export-led economy like South Korea. According to Westphal (1990):

> Korea provides an illuminating case of state intervention to promote economic development. Like many other third world governments, Korea's government has selectively intervened to affect the allocation of resources among industrial activities. It has also used similar policies: taxes and subsidies, credit rationing, various kinds of licensing, and the creation of public enterprises...but these policies have been applied in the context of a radically different development strategy, one of export-led industrialization.[8]

If one follows a Schumpeterian approach to technology creation as a cascade of interlinked systemic activities, the possibilities for economies of scale and scope leading

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[8] Larry Westphal (1990), 'Industrial Policy in an Export-Propelled Economy: Lessons from South Korea's Experience', The Journal of Economic Perspectives (summer), 41.

to the establishment of a POLIS arise out of the conjunction of a market system open to the world economy and selective interventions. Promotion of targeted infant industries has been part of this strategy of selective interventions in Korea. Examples include cement, fertilizer and petroleum refining in the 1960s. These were followed by steel and petrochemicals. In the late 1970s, shipbuilding, other chemicals, capital goods and durable consumer goods appeared on the list. More recently, electronic and information technologies are being promoted. Do these industries innovate? Even if they individually do innovate, do the industrial, governmental and social institutions connected to the innovation process add up to an innovation system? Furthermore is the innovation system, if it exists, characterized by positive feedbacks?

One quantitative indicator of the possibility of an innovation system would be the trend in R&D. Table 5 shows the major R&D indicators in Korea. Between 1965 and 1990 the expenditures increased more than 500 times. However the major take off has really been since the mid-1980s. Noticeable also is the reversal of the roles of public and private sectors. In 1990 the private sector provided 84 percent of R&D funds.

The number of research personnel is also an important indicator of the possibilities of a national innovation system. In the case of Korea, the number of core scientists increased by more than 30 times between 1965 and 1990. Here again, companies and universities are now the first and second largest employers of researchers, respectively.

Table 5: **Major R&D Indicators in Korea**

	1965	1975	1980	1985	1990
R&D expenditure ($ Million)	8	88	321	1298	4481
Funds from government (A)	7.2	59	186	247	717
Funds from private sources (B)	0.8	29	135	1051	3764
A:B	90:10	67:33	52:48	19:81	16:84
R&D/Manufacturing sales (%)	n.a.	0.35	0.65	1.51	2.07
GNP ($Million)	2759	20,952	55,345	87,703	234,607
R&D/GNP (%)	0.29	0.42	0.58	1.48	1.91
R&D researchers (persons)	2765	10,275	18,434	41,473	70,503
Research institutes	n.a.	5308	4598	7154	10,434
Universities	n.a.	2312	8695	14,935	21,332
Companies	n.a.	2655	5141	18,996	38,737
R&D researchers per 10,000 pop.	1.0	2.9	4.8	10.1	16.4

Source: Ministry of Science and Technology, Report on the Survey of Research and Development in Science and Technology, various issues; Linsu Kim (1993), *op. cit.*, p. 370.

Another important indicator of an innovation system is the number of patents. In the late 1980s and early 1990s the number of Korean patents grew, on the average, at a rate of 17.1 percent (see table 6). In absolute terms, however, Korea seems to be still far behind the advanced industrial nations.

Table 6: **Trends of Industrial Property Rights Applied by Korean and Foreign Nationals**

(Unit: case, %)

	1986	1989	1990	1991	Average Growth Rate (1986-91)
Patents	12,759	23,315	25,820	28,132	17.1
Utility Models	22,401	21,530	22,654	25,895	2.9
Industrial Designs	18,731	18,196	18,769	20,097	1.4
Trade Marks	28,031	39,832	46,826	46,612	10.7
TOTAL	81,922	102,873	114,069	120,736	8.1
Korean Nat'ls	63,256	68,300	81,713	90,659	7.5
Foreign Nat'ls	18,666	27,271	32,356	30,077	10.0

Source: The Office of Patents Administration, Patents Annals, various issues.

One special feature of the Korean industrial system in general and its innovation system in particular, is the role played by its **chaebols**, the big business conglomerates in developing and improving industrial technologies. With a large endowment of capital and modern complex organizational structure the chaebol can recruit the best human resources, identify and purchase the best foreign technology and obtain preferential financing. Since many observers are offering extremely pessimistic prognosis of their current debacle it needs to be pointed out that a few chaebols have also established R&D and technical training facilities recognizing the importance of in-house R&D capability.

At the microeconomic level R&D capacity building by a firm can be illustrated by discussing the example of Samsung Electronics Company (SEC). SEC is Korea's largest integrated electronics company. Table 7 shows the diverse product lines of SEC.

Table 7: **Major Product Line-up of SEC**

Business Sector	**Product Line**
Audio and Video Business	TV, LCD Projector, VCR, Camcorder, Component Audio, CDP, MD, DCC, LDP, MOD, CD-I, CD-ROM
Consumer Electronics Business	Refrigerator, Microwave Oven, Air Conditioner, Washing Machine, Vacuum Cleaner
Computer System Business	Mini Computer, Micro Computer, Desk-Top PC, Lap-Top/Note PC, Pen Base PC, Palm-Top PC, Network System, Work Station, Optical Filing System, Teleconference System, CTS, BAS
Telecommunication System Business	TDX, Modem, MUX, PAD, Facsimile, Typewriter, Copier, Key Phone, Pager, Car Phone, Hand-held Phone, Optical Communication System, Optical Fiber
Memory Devices Business	DRAM, SRAM, EEPROM, MASK ROM, Specialty Memory, TPH, TFT, LCD, CIS

Micro Devices Business	Discrete, MOSIC, Linear IC, ASIC, Logic IC, Micro Component, DSP

Source: Public Relations Office, Samsung Electronics, Creativity and Innovation (1993), p. 47.

In the semi-conductor field, Samsung developed 64K DRAMs in 1983. In 1990 it shared in the making of 16M DRAM. SEC also exports an electronic switching system (Time Division Exchange or TDX) to other LDCs. It also manufactures digital, cellular and satellite transmission systems. It is also active in fiber-optic communication systems. SEC offers a full line of products in the micro-computer field. Perhaps better known among consumers is the line of consumer electronics products of SEC ranging from TV to microwave ovens.

Table 8: **SEC's Three-tiered R&D System**

	Samsung Electronic Company		Samsung Advanced Institute of technology
	Integrated Research Centers	Research Team and Design Office attached to Business Sector	
ROLE	Establishment of technological foundation for growth of company Strengthening of Cooperation with SAIT	Maximization of company's profit	Establishment of technological foundation for the growth of the Group Technical supports to affiliate companies
RESEARCH AREA	New products development and commercialization on a short- and mid-term basis	Commercialization of new products on a short-term basis Diversification of models, improvement of functions and cost reduction of existing products	Development of new products on a mid- and long-term basis Development of core technologies, bottle-neck technologies, and new materials and parts

Source: Twenty Years History of SEC, 837.

SEC has a three tiered R&D system shown in table 8. Samsung Advanced Institute of Technology (SAIT) carries out research into basic or core technologies. Application technology and mid-term projects are the responsibility of the research centers associated with SEC's four business sectors. Finally, on the production technology side research teams attached to each division unit work closely with production and marketing people to make new or improved products.

The discussion so far shows the strengths and limitations of both the standard macro and micro approaches in addressing the question posed at the beginning of this section. At the macro level, statistical results may overstate or understate the overall innovative capability. At the same time the results on the whole warn against a casual optimism regarding East Asian growth in general and Korea in particular. The micro considerations show that in contrast to macro-pessimism some companies such as SEC do have considerable innovative capabilities. However, it is not obvious if the SEC experience is generalizable for Korea as a whole or even a few sectors. For this we need a multisectoral approach.

3.C. Modern Technology System in a SAM for Korea

The starting point for identifying the modern technology system in Korea in the late 1980s were the two earlier SAM-TECHs built by Thorbecke (1980)[9] and Khan (1985, 1997a). The accounts in the earlier SAM are given in the following table (sectors 1 to 77):

[9] The SAM-TECH built by Thorbecke can be found in Svejnar-Thorbecke (1980, 1982).

Table 9: **Endogenous Accounts in the SAM-TECH for South Korea, 1988**

1	Engineers
2	Technicians
3	Skilled workers
4	Apprentices
5	Unskilled
6	White collar
7	Self-employed (manufacturing)
8	Self-employed in service
9	Capital
10	Agricultural workers
11	Workers in farm size 1
12	Workers in farm size 2
13	Workers in farm size 3
14	Workers in farm size 4
15	Government workers
16-30	same as 1-15 except that they now refer to households as opposed to factors
31	Cereals
32	Other agriculture
33	Fishing
34	Processed food (M)
35	Processed food (T)
36	Mining
37	Cotton yarn (M)
38	Cotton yarn (T)
39	Woolen and worsted yarn (M)
40	Woollen and worsted yarn (T)
41	Other (M)
42	Other (T)
43	Cotton fabric (M)
44	Cotton fabric (T)
45	Woollen and worsted fabric (M)
46	Woollen and worsted fabric (T)
47	Others
48	Finished textile products
49	Lumber and furniture
50	Chemical products (M)
51	Chemical products (T)
52	Charcoal and wood
53	Crude Oil
54	Coal (M)

55	Coal (T)
56	Briquettes
57	Dried coal
58	Fuel oils
59	Gasoline
60	Carbide
61	Electricity
62	Gas services
63	Cement, non-metallic mineral products
64	Metal products (M)
65	Metal products (T)
66	Machinery
67	Transport equipment
68	Beverages and tobacco (M)
69	Beverages and tobacco (T)
70	Other consumer products
71	Construction
72	Real Estate
73	Transportation and communication
74	Trade and banking (M)
75	Trade and banking (T)
76	Education
77	Medical, personal and other services
78	Research and Development

Note: M= Modern, T = Traditional

As the reader must have noticed, in the above table, the modern SAM-TECH (ModSAM-TECH) is constructed by adding R&D rows and columns. Thus a 78 X 78 endogenous account SAM is formed. The focus is on identifying productivity and value added changes; but some attention also needs to be paid to the distributional characteristics of the innovation system.

Furthermore, in line with a strategy outlined in Khan (1997c, 1998 forthcoming) two successive approximations for two different scale levels are made. One is for 1986 GDP and the second is for the increment in two years. In the latter case co-efficients are changed **in proportion** to growth. This is most probably a lower bound increasing returns assumption. On the whole this involves a change in average propensity of investing in high technology sectors less than five percent.

The simple multiplier exercises indicate a modest POLIS effect. For each one percent injection of R&D output in the ModSAM-TECH increases by 2.5 percent. The modern technological system shows a range of increase varying between two percent and 3.6 percent.

In summary, in this section I have considered the claims about the growth process in Korea by both the miracle-makers and the miracle-breakers. A detailed investigation at the sectoral and micro level raises the possibility of a POLIS in Korea's modern technology system. An approximate and crude empirical implementation of the formal model of POLIS via a SAM-TECH for Korea confirms this modest expectation. However, Korea now faces the challenge of innovating in an increasingly competitive global environment. Also, the rewards from innovation, even if the Korean POLIS becomes a reality, would seem to be unevenly distributed.[10]

In retrospect, the ability of a small, open economy to build an innovation system may be seen to depend crucially on the strategic complementarity between R&D promoting activities and human capital deepening processes. While the human capital aspects of Korean development have been explored extensively, the understanding of the R&D process and its complementary relation with human capital remains incomplete. The results of this section, however tentative, can provide further motivation for such studies for Korea and other countries.

10 The Schumpeterian creative destruction leads to rents for successful firms; but the distribution of the rents depend on the existing social compact between labor and capital.

Conclusion

The paper has presented a somewhat novel theory of innovation based on the idea of, Managed Creative Destruction(MCD). This theory acknowledges the role of both the state policies and market processes. It should be emphasized that neither institution can guarantee sustained innovation processes. Paraphrasing Jefferson, we could say that the price of innovation is eternal vigilance. This vigilance combined with ingenuity on the parts of both state and market actors is a necessary condition for a sustained econmy wide innovation sytem.

The theory of Managed Creative Destruction(MCD) was used in this paper to build a multisectoral model of innovation. It was also emphasized that the roots of Managed Creative Destruction(MCD) are in Schumpeter's idea of technical progress as creative destruction in a market system. In our approach economic growth is the outcome of both technological progress and changes in aggregate demand over time. Therefore, it can be said that it combines the Keynesian idea of effective demand with Schumpeterian creative destruction. One can also locate the model more generally within what Richard Goodwin has called the MKS (Marx-Keynes-Schumpeter) class of models. The political economy approach of state-market interaction followed here makes it somewhat distinct from the classical approaches.

The model proceeds at the multisectoral macro level but is consistent with microfoundations such as the one given by Aghion and Howitt (1992). It goes somewhat further than some of the existing models by considering both physical and human capital as well as the interaction between the two. As expected, R&D plays a crucial role, but without complementary human capital, the positive feedback loop innovation structure (POLIS) can not be built.

The model could be extended theoretically by making technical progress bounded so that return to innovations could eventually fall. Also, the relationship between technical change and business cycle could be explored further. The illustrative example of Korea indicates the usefulness of the POLIS approach. Future empirical work could explore the role of POLIS in developing as well as developed countries.

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