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An Empirical Investigation on the Dynamics of Knowledge and IT Industries in Korea

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Abstract**—**Knowledge and IT inputs to other industrial production have become more important as a key factor for the competitiveness of national and regional economies, such as knowledge economies in smart cities. Knowledge and IT industries lead the industrial innovation and technical (r)evolution through low cost, high efficiency in production, and by creating a new value chain and new production path chains, which is referred as knowledge and IT dynamics. This study aims to investigate the knowledge and IT dynamics in Korea, which are analyzed through the input-output model and structural path analysis. Twenty-eight industries were reclassified into seven categories; Agriculture and Mining, IT manufacture, Non-IT manufacture, Construction, IT-service, Knowledge service, Non-knowledge service to take close look at the knowledge and IT dynamics. Knowledge and IT dynamics were analyzed through the change of input output coefficient and multiplier indices in terms of technical innovation, as well as the changes of the structural paths of the knowledge and IT to other industries in terms of new production value creation from 1985 and 2010. The structural paths of knowledge and IT explain not only that IT foster the generation, circulation and use of knowledge through IT industries and IT-based service, but also that knowledge encourages IT use through creating, sharing and managing knowledge. As a result, this paper found the empirical investigation on the knowledge and IT dynamics of the Korean economy. Knowledge and IT has played an important role regarding the inter-industrial transactional input for production, as well as new industrial creation. The birth of the input-output production path has mostly originated from the knowledge and IT industries, while the death of the input-output production path took place in the traditional industries from 1985 and 2010. The Korean economy has been in transition to a knowledge economy in the Smart City.

Keywords**—**Knowledge and IT industries, input-output model, structural path analysis, dynamics of knowledge and IT, knowledge economy, knowledge city, smart city.

I. Introduction

It seems that a smart car is an automobile as well as a computer. The Smart City can hear, see, smell, touch and feel through IT sensors embedded in smart infrastructure and buildings which can decide whether to ring a fire-alarm or not, through knowledge-based artificial intelligence on building fires. Knowledge and IT create a new commodity, as well as make industries more innovative. Increasing knowledge and IT convergence brings to the smart to all, from technological convergence to social convergence.

It was only a few decades ago when the knowledge and IT-based smart fever began in just about every possible industry and city. The global economy transitioned from an agricultural economy to a knowledge-based economy through the industrial economy. The smart leads of the Smart City and the knowledge economy from the hardware and software perspectives [7].

In regard to hardware, the Smart City has been planned and built with ubiquitous infrastructure. After Mark Weiser coined the term, ubiquitous computing, ubiquitous city, digital city and Smart City were introduced and built in Amsterdam (Netherland), Stockholm (Sweden), Songdo (Korea), Barcelona (Spain), Singapore, India and China [8].

In terms of software, the knowledge economy was built through the knowledge and IT (Information technologies or ICT information communication technologies) input to other industries through making more productive use of inputs, and by increasing the value-added and creating new production path chains.

After Peter Drucker introduced the initial foundation for the knowledge economy in 1967, and today, global examples of the knowledge economy are found at Silicon Valley (USA), Munich (Germany), Hyderabad (India), Cambridge Science Park (UK), 22@Barcelona (Spain), Arabianranta (Finland), Strijp-S (Netherlands), and Digital Hub (Ireland), and Daeduck Science Park and Digital Media City (Korea) [6].

The Smart City requires IT-embedded intelligent buildings and infrastructure which lead the knowledge economy. Smart city makes traditional industries innovative and creates the knowledge intensive companies as well as IT-initiated new industries. According to the OECD statistics the proportion of the GRDP for the knowledge industry in OECD countries accounted for 25% in 1995 and the proportion surged to nearly 50% in 2010 [9]. Knowledge and IT are at the core of the Smart City and a knowledge economy, and open a new era to enhance the quality of life, to foster new industries and to strengthen national competitiveness, which is referred to as knowledge and IT dynamics. In spite of an assertion with respect to knowledge and IT dynamics, there is little research to address the empirical investigation of knowledge and IT dynamics.

This study aims to investigate the evidence of the knowledge and IT dynamics in Korea. Korea is a representative example of the Smart City and a knowledge economy, and has pushed forward to implement Smart City policy to increase the quality of life and strengthen national competitiveness since the 1980s

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[7]. This paper focused on uncovering the evidence of knowledge and IT dynamics. This paper argued firstly whether Korean economy has been transitioned to knowledge economy or not, secondly whether knowledge and IT are important in the industrial production process from 1985 to 2010 or not, thirdly whether traditional industries are converged with knowledge and IT or not, and fourthly whether new production paths were created or existing production paths became extinct in relation to knowledge and IT.

The knowledge and IT dynamics are analyzed through input-output model and structural path analysis based on the input-output data, 28 industrial classifications published by the Bank of Korea in 1985 and 2010 [10], [11]. The 28 industries were reclassified into seven categories; Agriculture and Mining (AM), IT Manufacture (ITM), Non-IT Manufacture (NITM), Construction (C), IT-Service (ITS), Knowledge Service (KS), Non-IT etc. Service (ES) to take close look at the knowledge and IT dynamics. The input-output model analyzes the knowledge and IT dynamics through the change of input output coefficients a_{ij} and input output multipliers b_{ij}. The input output coefficients a_{ij} are the index to analyze the technical innovation and the input output multipliers b_{ij} are the indicator to analyze the impact of knowledge and IT to other industries. The structural path analysis explains how many production paths were newly created and IT, as well as how to promote innovation in industries through knowledge and IT.

II. Research Model and Data

A. Research Model

The input-output analysis and structural path analysis were used as a research model. Input-output model analyzed the interdependence of industries based on the input-output coefficient a_{ij} and the input-output multiplier b_{ij}. The input-output model is as follows: $X = (I-A)^{-1} F$, where X is the matrix of total gross outpour of industries, A is the matrix of a_{ij} and F is the matrix of final demand of industries.

The coefficient a_{ij} is measured as $a_{ij} = \frac{z_{ij}}{X_j}$ where a_{ij} is the input-output coefficient, z_{ij} is intermediate input delivered from i-industry to j-industry, and X_j is the total gross output of j, and where a_{ij} represents the technical coefficient in terms of the ratio of intermediate input combinations for production. This paper will investigate the importance of knowledge and IT in the production process with a_{ij}.

Multiplier b_{ij} is measured as $(I-A)^{-1}$, where A is a set of a_{ij} and I is identity matrix. Where b_{ij} is the input-output multiplier coefficient, which means the direct and indirect requirement of output per unit of sectoral final demand [3]. This paper will investigate how much effect knowledge and IT has on other industries through a_{ij} and b_{ij}.

Structural path analysis is the back-tracking process of the input-output multiplier in terms of decomposing the input-output multiplier. It analyzed the changes that take place in inter-sectoral linkages in the process of diversification, and the roles of sectors in such changes [1]. This paper will investigate what kind of new value and production path chains are created or made redundant in relation to knowledge and IT through structural path analysis. Fig. 1 shows various paths of the input-output multiplier from i industry to j industry. x, y, z, s, v represented various industries on the path of the input-output multiplier bji. Structural path analysis consists of three elements: direct effect, total effect and global effect.

Direct effect path of (i-s-j) is calculated on the product of asi ajs. The direct effect of i on j transmitted through an elementary path is the change in production of j induced by a unitary change in i, the production of all other poles except those along the selected elementary path remaining constant. Total effect path of (i-x-y-j) is calculated on axi · ayx · ajy [I - ayx (axy + azy · axz)]-1. Total effect cumulates, when the direct effect has transmitted along the latter and the indirect effects induced by the circuits adjacent to that same path [2]. The global effects of bji from pole i to pole j simply measures the total effects on output of pole j consequent to an injection of one unit of output in pole i. Hence, global effect cumulated all induced and feedback effects resulting from the existence of circuits in the graph as shown by Fig. 1.

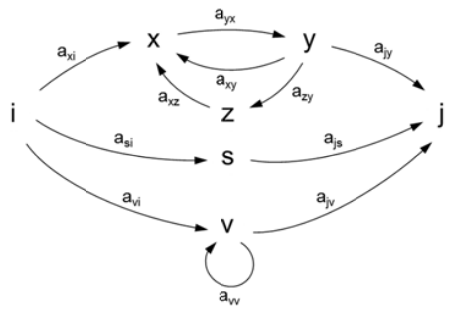

Fig. 1 Network of elementary paths and adjacent circuits linking poles i and j [2]

B. Data

This paper used the input- output table published by the Bank of Korea in 1985 and 2010. The 28 industries were reclassified into seven categories, Agriculture and Mining (AM), IT Manufacture (ITM), Non-IT Manufacture (NITM), Construction (C), IT-Service (ITS), Knowledge Service (KS), Non-IT etc. Service (ES) to take close look at knowledge and IT dynamics. IT was reclassified into ITM as hardware and ITS as software in detail.

The input-output table records the flows of products from each industrial sector considered as a producer to each of the sectors considered as consumers. The input-output data showed that industrial production in 25 years from 1985 increased by 1,584%, from 270 trillion won (231.65 billion dollars) in 1985 to 4,276 trillion won (3,669 billion dollars)[1] in 2010.

The growth rate of ITM, KS and ITS production has increased by 3,855%, 2,722%, and 2,444%, respectively, greater than the average growth rate of 1,584% during the period from 1985 to 2010. The production of ITM increased the

[1] Corresponding US dollar amount calculated at 1USD = 1,165.53 KRW (06/06/2016 daily rate)

most, followed by KS and ITM, while AM has increased the least.

The share proportion of KS, ITM and ITS production to gross total industrial production shows a steadily increase of 7%, 5%, 0%, while AM, NITM, C, and ES show a decrease by -5%, -3%, -1%, and 0%, respectively, during the period from 1985 to 2010. NITM has still accounted for 28% of total industrial production in 2010, highest among all industries. As was suggested by Table I, IT and knowledge-based industries lead to national economic growth.

TABLE I
THE CHANGE OF INPUT-OUTPUT PRODUCTION (UNIT: TRILLION WON)

Industry	Production Share		Share Change	**Production Growth Rate**
	1985	2010	2010-1985	**1985-2010**
AM	15.7(6%)	56.5(1%)	-5%	**359%**
ITM	9.3(3%)	358.1(8%)	5%	**3855%**
NITM	85.9(32%)	1211.6(28%)	-3%	**1411%**
C	20(7%)	265.4(6%)	-1%	**1332%**
ITS	2.4(1%)	59.4(1%)	0%	**2444%**
KS	54.5(9%)	666(16%)	7%	**2722%**
ES	33.3(12%)	507(12%)	0%	**1521%**
Total	**270.1(100%)**	**4276.6(100%)**	**-**	**1584%**

III. ANALYSIS RESULT

A. Input-output Coefficient Analysis

Table II included the input-output coefficient a_{ij} and its change in terms of demand and supply. The intermediate input row sum, in terms of sales, noted that the growth rate of KS, ITS, and ITM's intermediate input to other industries were 209%, 171%, and 124%, respectively, which were equal or greater than the 124% average of the past 25 years. The growth ratio of THE ES intermediate input was 135%, while AM, NITM, and C were just under the average. The demand for KS increased the most, followed by ES, ITM and ITS.

The intermediate input column sum showed that ITS has had the greatest growth rate at 321% from 0.1737 in 1985 to 0.5571 in 2010. That is, ITS has used the products of other industries as the intermediate input more in 2013 than in 1985 to increase its production. Knowledge and IT encourage other industries to enhance production and value−add through innovation.

ITM purchased the most intermediate inputs, followed by NITM (0.7724) and ITS (0.5571) in 2010, while NITM (.07575) used the most intermediate input, followed by ITM (0.7276), C (0.5574) in 1985. The highest ranking of the intermediate column sum changed from NITM (0.07575) to ITM (0.7724) during the 25 year period.

NITM (1.4809) sold most of its product to all industries, followed by ITM (0.4646) in 1985. There was no the ranking change of the intermediate row sum. The second in the overall ranking changed from ITM (0.4646) to KS (0.07265). Therefore, the answer is YES, to the question: "Is knowledge and IT important in the production process?"

TABLE II
THE RESULT OF INPUT-OUTPUT COEFFICIENT ANALYSIS

Industry	Intermediate Input Column Sum			Intermediate Input Row Sum		
	1985	2010	Growth Rate	1985	2010	Growth Rate
AM	0.3366	0.4684	139%	0.3092	0.3031	98%
ITM	0.7276	0.7824	108%	0.4646	0.5757	124%
NITM	0.7575	0.7724	102%	1.4809	1.5758	106%
C	0.5574	0.6290	113%	0.1753	0.1588	91%
ITS	0.1737	0.5571	321%	0.1153	0.1975	171%
KS	0.3008	0.3730	124%	0.3474	0.7265	209%
ES	0.4818	0.5525	115%	0.4425	0.5978	135%
Total	3.3354	4.1351	124%	3.3352	4.1352	124%

B. Input-Output Multiplier Analysis

The input-output multiplier, as shown in Table III, explained that the direct and indirect impact among industries rose as much as 3.5 and increased by 123% by 2010. In particular, the ITM multiplier increased the most from 3.0202 in 1985 to 3.5126 in 2013, while the ITS multiplier shows the greatest growth rate at 170% from 1.6601 in 1985 to 1.9109 in 2013. ITM has the strongest impact on other industries, while the ITS increase impacts the growth rate the most.

ITM (3.0202) had a greatest influence on all industries, followed by NITM (2.8676), C (2.4322) and ES (2.169) in 1985. There was no ranking change during the 25 years of the study. ITM, ITS and KS had a greatest impact on NITM and AM. Knowledge and IT encouraged all industries to create value-added. In the process of production, knowledge and IT dynamics took place with knowledge and IT having direct and indirect impacts on industries.

TABLE III
THE RESULT OF INPUT-OUTPUT MULTIPLIER ANALYSIS

Industry	1985	2010	Growth Rate 1985-2013
AM	1.8166	2.4024	132%
ITM	3.0202	3.5126	116%
NITM	2.8676	3.3583	117%
C	2.4322	2.8339	117%
ITS	1.3670	2.3249	170%
KS	1.6601	1.9109	115%
ES	2.169	2.4775	114%
Total	15.3327	18.8205	123%

C. Structural Path Analysis

The structural path analysis, as shown in Table IV, reported that 261 production paths were newly created by developing new value chains and enhancing value-added, while 32 production paths were phased out. A total of 228 of the 261 new paths were related to knowledge and IT, both directly and indirectly. While 128 paths were newly created directly, 100 paths were formed indirectly through a relation to knowledge and IT.

Of the 128 direct paths have been created, 59 are production paths of ITS, 36 are paths of ITM and 33 are paths of KS. ITS not only created the most new and various paths, but also were most dynamic in leading the knowledge economy. Due to the fast creation and superseding of leading-edge technology, the life cycle of ITS was very short, and a range of new ITS have also been developed and terminated.

Out of the 100 indirect paths, 38 took place in ITS, followed by 30 in NITM, 25 in ITM, 23 in ES, 18 in AM, and 16 in C. Traditional industries such as NITM, ES, AM, C had a greater share of new production paths than the average of 50%. It means that cutting-edge technology IT and knowledge-based industries were combined with traditional manufacturing and service to lead the innovation of traditional industries and to create new business value chains.

Regarding the demand and supply of knowledge and IT, the demand paths of ITM and KS from other industries were more, while the supply or impact paths of ITS to other industries was more. The demand paths of ITM and KS from other industries were more than the KS ITM supply or initiated impact paths to other industries, which means that all industries consumed the products of ITM, and KS more than ITM and KS consumed the products of other industries. ITS is contrary to ITM and KS.

Knowledge and IT was promoting industrial restructuring through the more productive innovation, as well the birth and death of production paths. Most industries have needed scores of ITM, ITS, and KS inputs in the course of production. Finally, the answer is YES to the question: “Has the Korean economy transitioned to a knowledge economy” in terms of “Were new value and production path chains are created in relation to knowledge and IT?”

TABLE IV
THE RESULT OF STRUCTURAL PATH ANALYSIS (UNIT: NO)

Industry	Industry	Extinct Path	Newly Created Path
AM	Other Industries	0(0)	14(10)
Other Industries	AM	4(2)	18(8)
AM Total		**4(2)**	**32(18)**
ITM	Other Industries	2(0)	17(11)
Other Industries	ITM	1(0)	19(14)
ITM Total		**3(0)**	**36(25)**
NITM	Other Industries	1(1)	14(12)
Other Industries	NITM	4(1)	30(18)
NITM Total		**5(2)**	**44(30)**
C	Other Industries	3(1)	19(9)
Other Industries	C	2(1)	9(7)
C Total		**5(2)**	**28(16)**
ITS	Other Industries	8(2)	44(28)
Other Industries	ITS	5(3)	15(10)
ITS Total		**13(5)**	**59(38)**
KS	Other Industries	1(0)	7(3)
Other Industries	KS	0(0)	26(10)
KS Total		**1(0)**	**33(13)**
ES	Other Industries	1(0)	14(9)
Other Industries	ES	0(0)	15(14)
ES Total		**1(0)**	**29(23)**
ITM+ITS+KS Total		**17 (5)**	**128(63)**
AM+NITM+C+ES Total		**15(6)**	**133(100)**
All Industries Total		**32(11)**	**261(163)**

( ) is the number of the indirect knowledge and IT related paths. Indirect knowledge (KS) and IT (ITM, ITS) mean a type of AM – KS - NITM , NITM – ITS – ITM - ES, C – ITS - ES etc.

IV. CONCLUSION

This study aims to investigate the empirical proof of the knowledge and IT dynamics that confirm the Korean economy has transitioned to a knowledge-based economy. IT includes IT manufacturing industries such as computer hardware, software, electronics, semiconductors, and telecom equipment, as well as IT service industries that include Internet services, engineering, healthcare, e-commerce and computer services. Ordinary examples of knowledge industries are related to the education and research of software engineers, physicians, pharmacists, architects, engineers, scientists, public accountants, lawyers, and academics.

The data for analysis is the input-output table published by the Bank of Korea for 1985 and 2010. The input-output model and structural path analysis were used to identify the structural changes to a knowledge economy. An analysis of the results indicated that the evidence of knowledge and IT dynamics were investigated: Knowledge and IT played an important role in the overall industrial production process.

The input-output table showed that ITM, KS and ITS have lead GRDP growth during the period from 1985 to 2010. In taking a look at growth rate of 3,855% in ITM and 2,722% in KS, and comparing it to the average GRDP growth rate of 1,584%, in the past 25 years, KS showed the highest intermediate input growth ratio at 209%, followed by 171% in ITS and 124% in KS with encouraging industries to be innovative. The ITM multiplier was highest 3.0202 in 1985 and 3.5126 in 2010, while ITS had the greatest growth rate at 170%. The knowledge economy has transitioned in Korea through the creation the production paths in ITS (59 paths), ITM (36 paths) and KS (33paths). Out of the 261 newly created production paths, 228 paths were newly formed in knowledge and IT directly and indirectly, where 128 paths directly created and 100 paths indirectly formed.

Therefore, this paper provided the insight into knowledge and IT dynamics in the Korean economy. That is, IT and knowledge have transformed the Korean economy from an industrial economy to the knowledge economy during a period 25 years. Knowledge and IT have shown considerable growth from 1985 to 2013, with ITM, ITS, and KS claiming the largest share. Some IT technologies and knowledge have successfully adapted to the latest technology and industries, while many other technologies and industries simply disappear [9]. There were also various types of convergence of IT and knowledge in traditional areas of agriculture, manufacturing and services. New industries have emerged including software, embedded software, digital contents, smart device, 3D printing, ICT display, digital broadcasting, BcN and WiFi networks, IoT, the Smart car, and so on.

Innovation and evolution were developed through an interaction between knowledge and IT. It is said that IT not only fosters the generation, circulation and use of knowledge through IT hardware systems (ITM) and IT based services (ITS), but also that knowledge encourages IT use to create new ideas, to share information and to manage knowledge effectively. The transfer and sharing of knowledge between industry and academia is an important component of the success of manufacturing in regards to software. New digital technologies demand increasing innovation and sustainable

Smart Cities in regards to hardware.

Firms and other organizations are supporting the research and development of future technologies and products to establish interconnections between services and devices, and between devices and technologies [4]. Most companies focus their financial and human resources on achieving and expanding a greater market share of the global industry. In the telecommunications and energy sectors there are also many small and specialized companies at the cutting edge of the knowledge industry. The convergence of IT and knowledge, as well as the convergence of knowledge and IT with traditional industries, will continue and will last through the creation of new companies and industries, such as Google and Apple. Some cities advocate the concept of ‘knowledge cities and Smart Cities’ where innovative thinking and knowledge spill-over are fostered for local and national economic growth [5].

Appendix

The meanings of the abbreviation in this paper are as followings; A: Agriculture industries, ITM: IT Manufacture industries: NITM: Non-IT Manufacture industries, C: Construction industries, ITS: IT Service industries, KS: Knowledge Service industries, ES: Other Service industries.

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