경제학 석사 학위논문

Comparative study of National Innovation system efficiency of Poland in economic growth beyond the Middle-income trap

경제성장에 영향을 준 국가혁신시스템 효율성 비교연구

: 중진국함정을 극복한 폴란드 케이스를 중심으로

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박 상 현

Abstract

Poland is one of the few countries that has escaped from the middle-income trap (MIT: 20% to 40% of US GDP per capita, PPP) since 2008. This paper uses the USPTO granted patent data of 33 countries to analyze and compare the performance of national innovation systems (NIS). Five NIS variables, namely the knowledge localization, the cycle time of technologies, the originality, the decentralization and the diversification are used in cluster analysis to identify what type of the catching up NIS Poland belongs to. Since Poland' s economic growth beyond the MIT was not explained in much part by the accumulation of capital and labor, this paper measures the efficiency of NIS variables on total factor productivity growth, the unexplained part of the growth through data envelopment analysis.

Keyword : Middle Income Trap; Data Development Analysis; Cluster Analysis; National Innovation System; Patent; Catching-up
Student Number : 2016-26936

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Chapter 1.
Introduction

Gill and Kharas (2007) coined the term 'middle income trap' (MIT), a phenomenon wherein middle-income economies consequently failed to join the high-income economies and faced decelerated growth. World Bank (2012) classified middle-income economies (20% to 40% of U.S. per capita income) as the MIT. However, some economists have rejected the existence of this trap (e.g. Im and Rosenblatt, 2013; Han and Wei, 2017). The conflicting views regarding the existence of the MIT are due to the differences in the definitions of the trap and the methodologies to test its existence. Regardless of its existence, it is clear that many middle-income countries are struggling at the stagnant middle-income status[①].

The determinants of economic growth remain an important puzzle in economics. Diverse studies have investigated the key responsible components for the MIT such as institutions, foreign direct investment (FDI), research and development (R&D) expenditure, tertiary education level, resource-based production and the National innovation systems (NIS). Innovation capabilities have been recognized as the key binding constraints for the middle-income stage (Lee, 2013; Eichengreen, Park, and Shin, 2013; World Bank, 2010; Cirera and Maloney, 2017). The observation implemented by World Bank (2010) also supports this view that middle-income economies would tend to fall under the trap because their wage rates are too high to complete with low-wage economies and the level of their technology is too low to enable from them to compete with high-wage economies. The importance of innovation as the factor of the trap is also found in the success story of East Asian Economies (South Korea, Taiwan and China) wherein they made a transition from low-wage based goods to high-end goods exporter (Lee, 2013).

① A study by the World Bank (2012) showed that only 13 out of 101 middle-income economies have reached the high-income status since 1960.

When a limited part of economic growth can be explained by the accumulation of physical capital and working hours of labor, Total factor productivity (TFP) is considered as the unexplained part of economic growth, and refers to a measure of the efficiency with which labor and capital are used. Improvements in TFP reflects the development of production as a result of the adoption of the more efficient production technologies. It has been witnessed that a significant part of economic growth was attributed to TFP growth, and the gap in economic growth between countries can be largely explained by the differences in TFP of different countries.

This paper utilizes the concept of the national innovation system (NIS) as a key framework for economic growth, and analyzes the more concrete mechanisms by which innovation is generated. The national innovation system can be defined as the "elements and relationships involved in the production, diffusion, and use of new and economically useful knowledge that are located within the borders of a nation state" (Lundvall, 1992). For instance, R&D and tertiary education can be classified into NIS because R&D expenditure and the tertiary education level are related to the degree of knowledge creation and diffusion. In addition to R&D expenditure and tertiary education, the other focus of NIS shows on the technology life-cycle, the originality of technology, the knowledge localization, the technological diversification and the decentralization of technology within a country.

This paper will address how Poland has achieved economic growth through comparative analysis with other countries. Poland's economic success since 1989 is unique because it was the only large and democratic country among all post-communist economies. Poland with few natural resources has achieved its remarkable economic growth. In this study, the cluster analysis applies NIS variables to classify the NIS of countries into several types. By the clustering analysis, we could confirm which type of NIS cluster Poland belongs to. Then, Data envelopment analysis (DEA) can measure the relative efficiency of NIS variables for TFP growth in Poland.

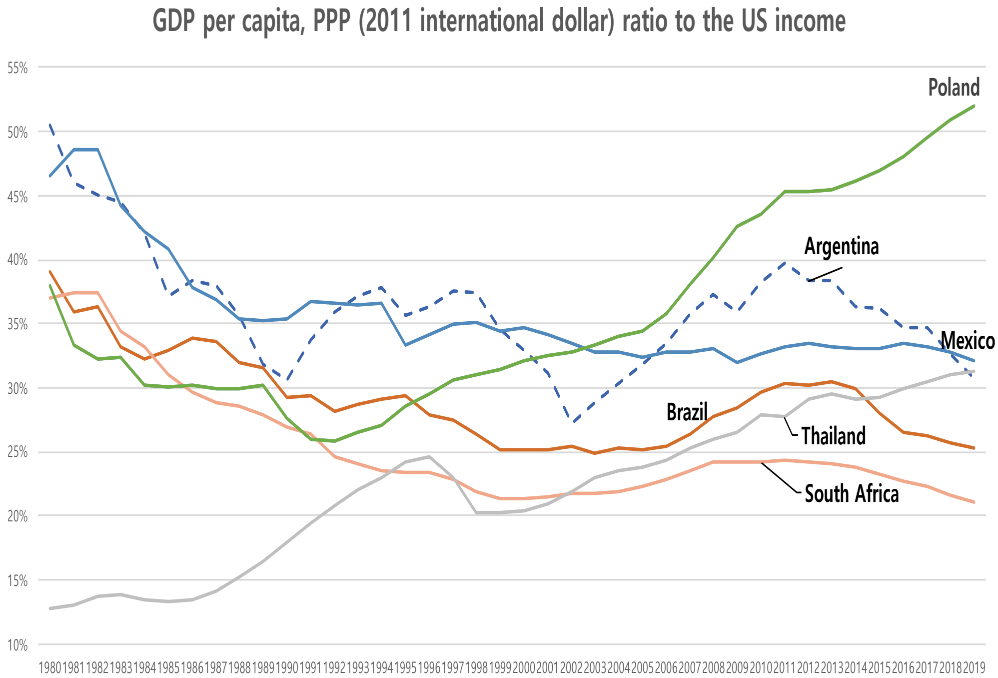
Chapter 2.
Record of Economic Catching up and Growth Accounting Results

2.1 Growth beyond the 'Middle income trap'

One way to measure a country's economic growth performance is by measuring relative income level to the USA per capita income. In this paper, the measurement uses GDP per capita (Purchasing Power Parity, 2011 international $) from IMF World Economic Outlook (WEO) to calculate the relative GDP per capita ratio to the U.S. per capita income in Figure 1A and 2B. 20~40 percent of the U.S. GDP per capita can be considered as the boundary of MIT. A country with more than 40 percent of the U.S. per capita income has successfully caught up.

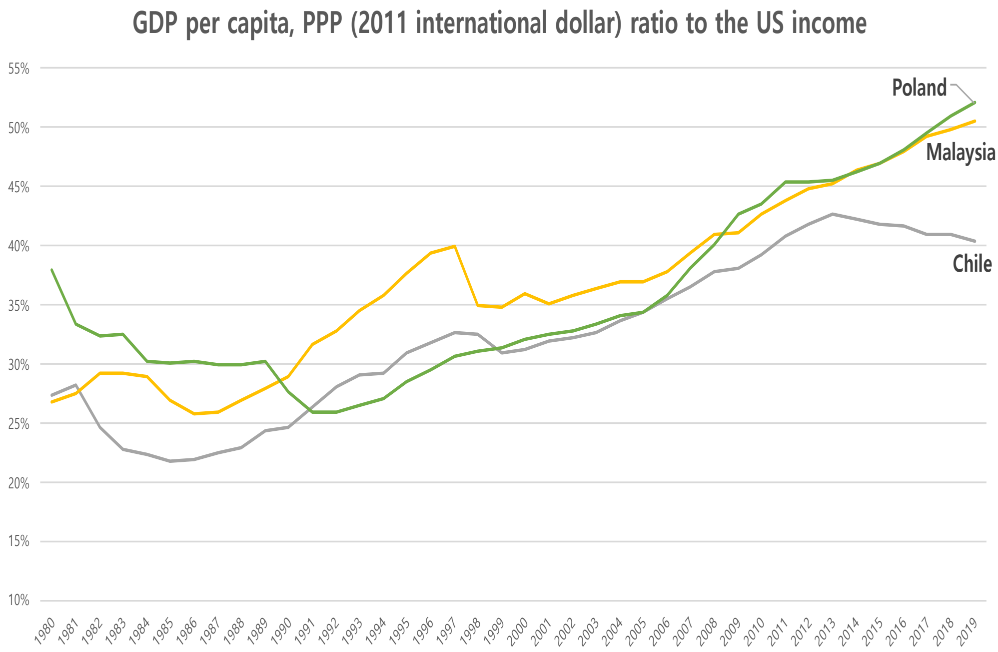
Shown in Figure 1A and 2B, it shows different economic performance by country. Poland appears to have achieved to transition towards a high-income economy. Poland, unlike most other middle-income countries, such as Brazil, Mexico, Argentina, Thailand, South Africa, exceeds 40% of the US GDP per capita (PPP) in 2008. The relative income level of Mexico and Argentina has declined from 46% and 50% in 1980 to 32% and 27% in 2003 respectively. Meanwhile, Thailand have grown from 12% in 1980 to 30% in 2019, however, fails to grow beyond the MIT. Figure 1B suggests that Malaysia and Chile have also been growing in the past decades and reached 40% in 2008 and 2011 respectively. Recent study of Chile and Malaysia analyzed by Lebdioui, Lee and Pietrobelli (2020) suggests that firms in the resource-based sector level close the technological gap with frontier capabilities.

Figure 1A. Middle Income Trap



Source: Author calculation based on IMF (2019) WEO April 2019 Edition

Figure 1B. Middle Income Trap



Source: Author calculation based on IMF (2019) WEO April 2019 Edition

2.2 Growth Accounting Results

Growth accounting decomposes economic growth into the contributions of capital, labor, and a residual measure of gains. This residual represents an estimate of the changes in TFP. The Cobb-Douglas aggregate production function is the organizing principle of growth accounting:

$$Y_{it} = {e_{it}}^{\theta} {K_{it}}^{\alpha} {L_{it}}^{\beta}$$

where Y_{it} is real GDP, θ is the growth rate of TFP, α represents the share of capital in GDP, β represents share of labor, K_{it} is capital stock, and L_{it} is employment. Differentiating the logarithm of the Cobb-Douglass equation with respect to each time period, we obtain

$$g = \theta + \alpha(GRK) + \beta(GRL)$$

where g is the growth rate in real GDP, θ is the growth rate of TFP, α shows the elasticity of output with respect to capital, GRK represents the growth rate of capital, β is the elasticity of output with respect to labor, and GRL is the growth rate of labor. This section adopts the results of Garbis Iradian (2007) where the fixed effects econometric technique with cross-section weights is used to estimate the shares of capital and labor.

Table 2 shows the differences in total factor productivity in each country that affected economic growth and output during 1996-2006 period. Poland accounts for 2.1 percent points of TFP growth contribution and 48 percent of TFP share in output. China also has high percent point of TFP growth contribution, 3.7 and 40 percent of TFP share in output. In contrast, developed countries such as France, Germany, Japan, and USA with relatively low level of real GDP growth rate has small percent points of TFP growth, 0.4, 0.4, 0.5, and 0.7 respectively. High TFP growth rate implies that a country relies on the growth in output with unchanged levels of the factor inputs.

Table 1. Growth Accounting Results (In percent, annual averages, 1996-2006) (Iradian, 2007)

	Real GDP Growth Rate	Investment (%GDP)	Contribution to Growth (Percent points)			Share of TFP in Output	Growth in Productivity of Labor
			Capital	Labor	TFP		
Poland	4.4	21	2.2	0	2.1	48	4.3
Czech Republic	2.9	28.9	2.3	-0.2	0.8	29	3.2
Hungary	4.2	22.9	2.3	0.4	1.5	36	3.6
Chile	4.3	22.9	2.4	1.2	0.6	14	2.2
China	8.8	36.8	4.4	0.8	3.7	40	7.4
Ireland	7.3	24.6	2.8	2.6	1.9	26	2.9
Korea, Rep	5.4	34.4	2.7	0.9	1.9	34	3.8
France	1.9	23.3	0.69	0.6	0.4	20	0.9
Germany	1.4	20	0.8	0.2	0.4	30	1.1
Japan	1.2	24.7	0.8	-0.1	0.5	41	1.3
USA	3.3	19.2	1.7	0.8	0.7	23	1.9

Note: Annual depreciation rate of capital stock is assumed at 5 percent; and the initial capital stock to GDP ratio of 2.

Chapter 3.
Literatures on the Polish Economic growth

FDI has been identified as the major contributor to the host economy's productivity growth with technology spillover across domestic firms (Grossman and Helpman, 1991). Poland-specific studies also find that integration into global production networks has contributed to movement into higher value-added activities (EBRD, 2014). Jan Hagemejer and Marcin Kolasa (2011) find that "all forms of internationalization, including ties to multinational companies, are positively associated with a range of favorable characteristics, including capital intensity, productivity and wage levels in Poland." Although FDI can have beneficial influence on the knowledge spillover in the early stage of economic growth, the eventual rise of indigenous firms becomes more important channel for gaining knowledge at later stage because foreign firms tended to reluctant to transfer technology[②] (Lebdioui, Lee and Pietrobelli, 2020; Amsden and Chu, 2003). Meanwhile, Polish economy is heterogenous with Multinational corporations (MNCs) playing a less prominent role than other Central and Eastern Europe countries (CEE), such as Hungary, the Slovak Republic. Poland's largest, domestically owned firms are relatively small, while indigenous industry heavily relies on small and medium sized firms (Breznitz and Ornston, 2017; Martin, 2013).

Empirical analysis of foreign direct investment in Poland indicates that FDI was not a significant factor for GDP growth, but a domestic expenditure on fixed capital and expenditure on R&D (Kosztowniak, 2013). According to Balcerzak and Zurek (2011), VAR analysis for Poland shows that FDI has only short-term positive influence on labor market. Moreover, according to Chase-Dunn, Kawana, and Brewer (2000), Poland can be one of the periphery countries which receive small share of global wealth and exploited by more developed countries.

After the 1989 revolution in Poland which caused the collapse of the People's Republic of Poland, Leszek Balcerowicz was elected as a deputy prime minister and led a program of reform financed by the IMF and the World Bank (Sachs, 1993). The program liberalized all prices and introduced market-oriented reforms including privatization. According to Marcin Piatkowski (2018), Poland made successful transition because of the improvement of institutions such as large private sector at the beginning of Transition, a legacy of Pro-Market

② East Asia promoted their innovation capability in the early stage of economic growth by leaning from Multinational corporations (MNCs) or through the OEM (Original Equipment Manufacturing) contracts with MNCs. The eventual rise of indigenous firms supports the success of East Asian economic growth (Amsden and Chu, 2003) reforms before 1989, healthy Banks, strong financial sector supervision, solid and pragmatic policy making, and increase in the volume and quality of education, and the high absorption of EU funds. He also argues that improvements in institutions such as the voice and accountability, the political stability and absence of violence, the government effectiveness, the regulatory quality, the rule of law and the control of corruption accelerate the economics growth of Poland.

However, as Lee and Kim (2009) suggests that institution matters for low and lower middle-income countries, institutions of Poland are improved in the early stage of transition (1989 – 1995). Moreover, the control of corruption variable and the government effectiveness has dropped from 73 in 1996 to 71 in 2015 and 77 in 1996 to 75 in 2015, respectively, compared to the counterpart, the upper middle-income economies improved from 47 to 49 and from 45 to 49, respectively (Piatkowski, 2018). EBRD index of institutional reform (1995-2012) also shows that Ukraine, Romania, Croatia, Bulgaria have improved the index more than 1 unit, whereas Poland have improved less than 1 unit in the period (ibid)

OECD has conducted studies on National innovation systems adopting the original definition of the NIS by Lundvall (1992), which focuses on four types of knowledge variables: interactions among enterprises, interactions among enterprises, universities and public research institutes, diffusion of knowledge and technology to enterprises and mobility of the skilled personnel (OECD, 1997). In 1992, OECD compared R&D intensity between catching-up economies and developed OECD countries as the simple indicators of NIS. However, few studies have implemented NIS of Poland as factors of the economic growth.

Chapter 4.

Measuring National Innovation System and Total Factor Productivity Growth Rate

4.1 National Innovation System

The NIS deals with the question of how efficiently a nation establishes a system for learning and innovation in terms of production, diffusion and utilization of knowledge (Lundvall, 1992; OECD, 1997). Various NIS variables such as investment climates and political institutions are used to measure the knowledge innovation capabilities. However, NIS variables affect the speed or direction of a nation's innovation and its economic performance. In terms of a catching-up perspective, how knowledge is efficiently produced, diffused and used among national agents matters.

Regarding the indicators of NIS, this paper focuses on knowledge flows measured by US granted patent data, research and development (R&D) expenditure and tertiary education level. US granted patent data can be retrieved from the USPTO bulk data wherein a weekly released US granted patent panel data available from 1976 to current contains information regarding inventor, assignee, cited patent, classification, etc. This paper screens countries with more than 40 granted patents in five years to measure NIS variables[③].

Cycle time of technologies

The cycle time of technologies (CTT) measures the time lags between the granted year of citing and cited patents or the time span between the predecessor and the successor (Jaffe and Trajtenberg,

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③ Chile meets the criteria from 1993; Malaysia from 1991; Thailand from 1993; Turkey from 2000

2002). The CTT variables shows whether countries specialized in sectors with rapid or slow obsolescence of knowledge. A long cycle time of technologies refers use of old knowledge and thus implies a greater entry barrier for the latecomers such as the pharmaceutical sector. Meanwhile, since a short CTT indicates the short life span of the knowledge, the less reliance on old technology and more opportunity for new technology promotes the latecomers to achieve economic growth (Lee, 2013).

This paper uses the relative cycle time of technology, not the absolute CTT. The average CTT of patent x_i granted in year t can be defined as follows:

$$\begin{aligned} &\textit{Average CTT of patent } x_i \textit{ granted in year } t \\ &= \frac{1}{n_x}\sum_{y_i}(\textit{granted year of citing patent } x \\ &- \textit{granted year of patent } y_i \textit{ cited by } x) \end{aligned}$$

where $y_1, y_{2,} \ldots . y_{n_x}$ represents patents cited by patent x_i. Then average CTT of country x in year t can be calculated as follows:

$$\begin{aligned} &\textit{Average CTT of country } x \textit{ granted in year } t \\ &= \frac{1}{\mathrm{N}}\sum_{x_i}(\textit{Average CTT of patent } x_i \textit{ granted in year } t) \end{aligned}$$

where N represents the total number of patents. The relative cycle time of technology of country x in year t can be achieved as follows:

$$\begin{aligned} &\textit{The relative CTT of country } x \textit{ granted in year } t \\ &= \frac{\text{average CTT of country } x \text{ in year } t}{\text{average CTT of all patents granted in year } t} \end{aligned}$$

Knowledge localization

Localization of knowledge creation and diffusion is about the source in the acquisition of knowledge and the degree of the intra-national creation and diffusion of knowledge (Jaffe, Trajtenberg and Henderson, 1993). An approach to compare the geographic localization of the patent citations owned by inventors of the same nationality suggests the probability of a patent matching the original patent by geographic region.

Based on the insight, this paper can measure how much knowledge is made domestically by citing the patents owned by same nationality inventors. The degree of knowledge localization in a country as the probability of one country's patents citing its own patents can be formally indicated as follows:

$$Knowledge_{xt} = A = \frac{n_{xxt}}{n_{xt}}$$

where n_{xxt} indicates number of citations made to country x's patents by country x's patents filed in year t, n_{xt} represents the number of all citations made by country x's patents filed in year t.

If the localization variable is large, then knowledge diffusion in the domestic level is high. In the cross-country panel analysis, Lee (2013) verified that the localization is positive and significant in high-income group regressions but not in middle-income group, implying that the knowledge localization may be unnecessary in the early stage of economic growth.

Technological Diversification

Diversification of technology captures the degree to which a country creates patents in a wide variety of technological fields. This variable represents a width of nation's technology portfolio (Lee and Lee, 2019). Using the three-digit class in CPC classification, the diversification variable is measured by the number of patent technology class in a country divided by 136, the total number of patent classes in the CPC and can be shown as follows:

$$Diversification_{xt} = (\frac{N_i}{136})_{xt}$$

where N_i indicates the number of technology classes that country x has filed in year t. Large technological diversification variable implies that the various technology is utilized and diffused in a nation.

Originality

The index of originality captures the degree to which a patent makes backward citations to patents from a wide range of technological class instead of a narrow range of the class (Trajtenberg, Henderson and Jaffe, 1997). The originality of patent x_i can be represented as follows:

$$Originality_{x_i t} = (1 - \sum_{k}^{N_i} (\frac{Ncited_{ik}}{Ncited_i})^2)_{x_i t}$$

where k is the technological class (US patent CPC classification), $Ncited_{ik}$ indicates the number of citations made by patent i to patents which belong to patent k and $Ncited_i$ is the total number of citations made by the patent i. The average for each country at year t for each patent represents the originality of country x in year t. If a patent cites previous patents which utilize a narrow set of technologies, the originality score will be low. High score of the originality variable represents a broad technological root of the underlying knowledge

Decentralization

Decentralization NIS variable investigates the degree of patent decentralization across assignees excluding unassigned patents, which measured by the Herfindahl-Hirschman index (HHI) of concentration

(Lee, 2013):

$$1 - HHI_{xt} = 1 - \sum_{i \in I_x} (\frac{N_{it}}{N_{xt}})^2$$

where I_x is the set of assignees, N_{it} indicates the number of patents granted by assignee i in year t and N_{xt} is the total number of patents granted by country x in year t. If the patents are filed by a small number of assignees, then HHI index is large, consequently, the decentralization variable have a high value.

Research and Development (R&D)

Most countries have invested on research and development (R&D) to promote innovations. The gross domestic expenditure on R&D indicator refers to the total expenditure on R&D financed by all resident enterprises, research institutes, university and government laboratories, etc. However, it excludes the expenditure performed abroad. According to the OECD's Frascati Manual (2015), research and development (R&D) can be defined as "creative work undertaken on a systemic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications." This paper utilizes the R&D expenditure (% GDP) using data from World Bank. R&D expenditure includes capital and current expenditures in the four main sectors: Business enterprise, Government, Higher education and Private non-profit. R&D covers basic research, applied research, and experimental development.

Tertiary education

As Lee and Kim (2008) suggests, tertiary education can be the key determinants of long-run economic growth for middle-income countries. The gross enrollment ratio for tertiary school can be calculated by dividing the number of students enrolled in tertiary education regardless of age by the population of the age group which officially corresponds to tertiary education, and multiplying by 100. Tertiary education, as an advanced research qualification, normally requires, as a minimum condition of admission, the successful completion of secondary level education. This paper uses the data from World bank wherein the education data are collected from national authorities' annual education survey and mapped to the International Standard Classification of Education (ISCED) to compare education programs at the international level.

Chapter 5.
Methods: The Cluster Analysis and The Data Envelopment Analysis

5.1 The Cluster analysis

The basic idea of clustering analysis determines which variables are used, measures the distance between units based on the selected variables and classifies clusters using the measured distance (Rokach and Maimon, 2005; Milligan and Cooper, 1985). The cluster analysis tests the degree of commonality among selected units in order to maximize the coherence of each cluster and the heterogeneity across different clusters.

Despite a growing interest on the measurement of various NIS and its effectiveness, few studies have been conducted to focus on the typology of the NIS over a large number of economies through cluster analysis with exceptions like Godinho, Mendonca and Pereira (2005), Castellacci and Archibugi (2008) and Lee and Lee (2019). Godinho et al. (2005) used 24 variables including 8 NIS variables[④] in 2002 or 2003 to analyze cluster over 69 countries and identified two or six clusters depending on the degree of aggregation. It also verified that three NIS variables related to innovation, diffusion and use of knowledge were more distinctive indicator than other remaining NIS variables. Castellacci and Archibugi (2008) identified six variables related to infrastructure, skills, and innovation using factor analysis. It also conducted a cluster analysis for 131 countries for year 1990 and 2000 and found three NIS clusters, i.e. advanced, followers, and marginalized. Recent study by Lee and Lee (2019) measured five NIS variables including the relative cycle time of technology, the decentralization, the localization of knowledge, the originality and the diversification of knowledge, using US granted patent data and conducted the cluster analysis of 32 countries for the period 2008 to 2015. It classified economies into five NIS clusters: Balanced and Mature NIS, Balanced Catching-up group, Imbalanced Catching-up NIS, Imbalanced and Trapped NIS, and Other-Balanced group.

Then, this paper utilizes five NIS variables of the average from 2006 to 2014, namely the relative cycle time of technology, the decentralization, the localization of knowledge, the originality and the diversification of knowledge to proceed with clustering analysis of 33 countries[⑤]. As indicated in the table 2, the number of patents granted in 33 countries from 2006 to 2014 is amount to 97.57% of all patent granted in the period. Because R&D expenditure (% GDP) and tertiary education enrollment rate data are missing in some countries, these two variables are not used in the cluster analysis. Unlike Lee and Lee

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④ which includes market conditions, institutional conditions, investment climate (educational and R&D investment), scientific knowledge (papers, researchers and college enrollment per capita, etc.), economic structure, openness and absorption, diffusion (internet host per capita), and innovation (patents and trademarks per capita)

⑤ United States, Japan, Sweden, United Kingdom, Italy, France, South Korea, Taiwan, China, Singapore, India, Hong Kong, Norway, Denmark, Turkey, Thailand, Poland, Malaysia, Mexico, Brazil, Chile, Argentina, Canada, Switzerland, Netherlands, Russia, Ireland, Israel, Spain, Greece, Portugal and South Africa.

(2019)'s study using U.S. classification in measuring NIS variables, this paper calculates NIS variables based on the CPC classification, which brings 16% more number of patents used to measure the variables in the same period. This paper focuses the NIS type of economies using the most recent period information, because some degree of inter-temporal stability of NIS types and the lag in NIS type changes in statistical method can be found: for example, South Korea started to specialize in short cycle time of technology sectors since the mid-1980s, a new NIS cluster was realized only in the 1990s. Also, this paper adopts the Euclidean complete linkage approach⑥ which uses the closest maximum distance between clusters, and applies a hierarchical classification method which provides a step-wise concentration of countries based on their distance.

⑥ Single complete linkage is as follows:
$D_1(X,\,Y) = \max_{x \in X,\, y \in Y} d(x,y)$, where $d(x,y)$ denotes Euclidean distance (L2 measure); $D_2\big((X,\,Y),Z\big) = max(\,D_1(X,Y),Z)$; For each stage, $\min Max(\,D_n[\{(X_1,X_2),X_3\},\ldots.])$

Table 2 The Values of the five NIS Variables in the Sample Economies: Average of 2006-2014

Countries	**Localization**	**Diversification**	**1-HHI**	**Originality**	**Relative cycle time of Technology**	**Average no. of Patents**
Argentina	0.03581649	0.21544118	0.9628071	0.38666853	1.064837	60
Brazil	0.02541821	0.48529412	0.9837945	0.39977801	1.031755	230.3
Canada	0.10460999	0.89926471	0.9831851	0.38746001	0.9464204	5667.7
Switzerland	0.12685825	0.84044118	0.9918857	0.37923979	1.029276	1925.7
Chile	0.02127565	0.21544118	0.9469322	0.41852942	1.108473	38.6
China	0.05750736	0.79558824	0.9704645	0.38516468	0.7549274	4503.7
Germany	0.19700172	0.92794118	0.990868	0.39196233	1.000531	13508.9
Denmark	0.09395652	0.67867647	0.985754	0.41141626	1.030806	831.5
Spain	0.04348685	0.625	0.9904327	0.38308761	0.9806761	589.5
France	0.14247655	0.89485294	0.9935656	0.388575	0.9963263	5190.2
United Kingdom	0.09153033	0.9	0.996423	0.39048801	0.9918148	5300.7
Greece	0.02029949	0.2	0.9398959	0.38730824	0.962701	53.4
Hong Kong	0.06440387	0.49485294	0.9872168	0.40287755	0.833252	480.2
Ireland	0.03823219	0.42941176	0.9755059	0.36450438	0.9349937	322.5
Israel	0.07117543	0.71764706	0.9897363	0.37366493	0.9181201	2254.4
India	0.02712429	0.56617647	0.9728602	0.36239927	0.8350285	1553.5
Italy	0.11887887	0.85294118	0.991158	0.39975877	0.9926968	2368.6
Japan	0.51466254	0.92941176	0.984374	0.36476252	0.8931838	46427.1
Korea, Rep.	0.20869517	0.86617647	0.8405161	0.35247964	0.7535685	12633.2
Mexico	0.03003636	0.41102941	0.9742138	0.41351694	1.062687	134.3
Malaysia	0.03469713	0.33161765	0.9366977	0.38646516	0.8681927	204.5
Netherlands	0.09266238	0.80441176	0.9542443	0.41193989	0.9946104	2089.8
Norway	0.07206451	0.58088235	0.9878458	0.39119007	1.059299	429.4
Poland	0.03586091	0.27573529	0.9615401	0.3666156	0.9302146	93.4
Portugal	0.02327425	0.17647059	0.931937	0.3973957	1.011528	37.8
Russian Federation	0.04528153	0.46691176	0.979091	0.37625348	0.9584729	305.9
Sweden	0.11780326	0.80588235	0.9721493	0.3764953	0.980248	1912.7
Singapore	0.04084921	0.51544118	0.9639424	0.36469012	0.8466372	694.1
Thailand	0.0204016	0.23455882	0.9441368	0.40981127	0.949604	67
Turkey	0.0092217	0.23088235	0.9482875	0.38684316	0.9696231	59.3
Taiwan	0.17883346	0.85588235	0.9858527	0.3702913	0.7525367	9901.4
United States	0.75509275	0.94044118	0.9961267	0.39050173	0.9398404	122383.6
South Africa	0.04802562	0.43455882	0.981366	0.40311985	1.11212	150.9
Total number of patents during 2006-2014						2157663
Number of patents of 33 countries during 2006-2014						2105245
Share of 33 countries during 2006-2014 (%)						97.570612

Source: Author's Calculation

5.2 The Data Envelopment Analysis

Data Envelopment Analysis (DEA) indicates the method of measuring the empirical production efficiency of decision making units

(DMUs) and has been widely used on studies measuring the efficiency of NIS. DEA finds production points defined as the production of a country with a given combination of input factors and calculates a frontier function by finding those production points which are under dominated in comparing every observed production point of sample country. This result represents a piecewise linear surface which envelops all observations of a sample and which is considered as a benchmark for the determination of the efficiency of all production points by measuring distance to the frontier function (Kruger, Cantner and Hanusch, 2000).

Through DEA, this paper investigated how efficiently the seven NIS variables (the relative cycle time of technology, the decentralization, the localization of knowledge, the originality and the diversification of knowledge, R&D (%GDP), the tertiary education enrollment rate) were used in the growth rate of total factor productivity. To measure the distance from the frontier function, the output-oriented version[⑦] of the DEA under constant returns to scale suggested by Charnes, Cooper and Rhodes (1978), i.e. CCR model was used:

$$\max_{\theta,u} \theta_h$$

$$s.t. \theta_h y_{hS} \leq \sum_{h=1}^{H} u_h y_{hS}, \qquad s = 1,2,\ldots,S\,,$$

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⑦ Output orientation is the more plausible assumption on the macroeconomic level because it is closer to the objectives of growth policy to achieve a product as high as possible with a given resource endowment (Kruger, et al., 2000) However, since this study uses TFP growth rate as an output, it may have negative outputs, so it may not able to calculate efficiency. Therefore, input oriented CCR model can also be used:

$$\min_{\theta,u} \theta_h$$

$$s.t. y_{hS} \leq \sum_{h=1}^{H} u_h y_{hS}, \qquad s = 1,2,\ldots,S\,,$$

$$\sum_{h=1}^{H} u_h x_{hn}, \qquad n = 1,2,\ldots,N,$$

$$u_h \geq 0, \qquad h = 1,2,\ldots,H$$

where θ_h is the efficiency measure of DMU_h, y_{hS} is amount of output s produced by DMU_h, x_{hn} is amount of input n used by DMU_h, and u_h denotes intensity variable for DMU_h.

$$\sum_{h=1}^{H} u_h x_{hn} \leq x_{hn}, \qquad n = 1,2,\dots,N,$$

$$u_h \geq 0, \qquad h = 1,2,\dots,H$$

where θ_h is the output efficiency measure of DMU_h, y_{hS} is amount of output s produced by DMU_h, x_{hn} is amount of input n used by DMU_h, and u_h denotes intensity variable for DMU_h.

Chapter 6.
Cluster Analysis Results and NIS comparison.

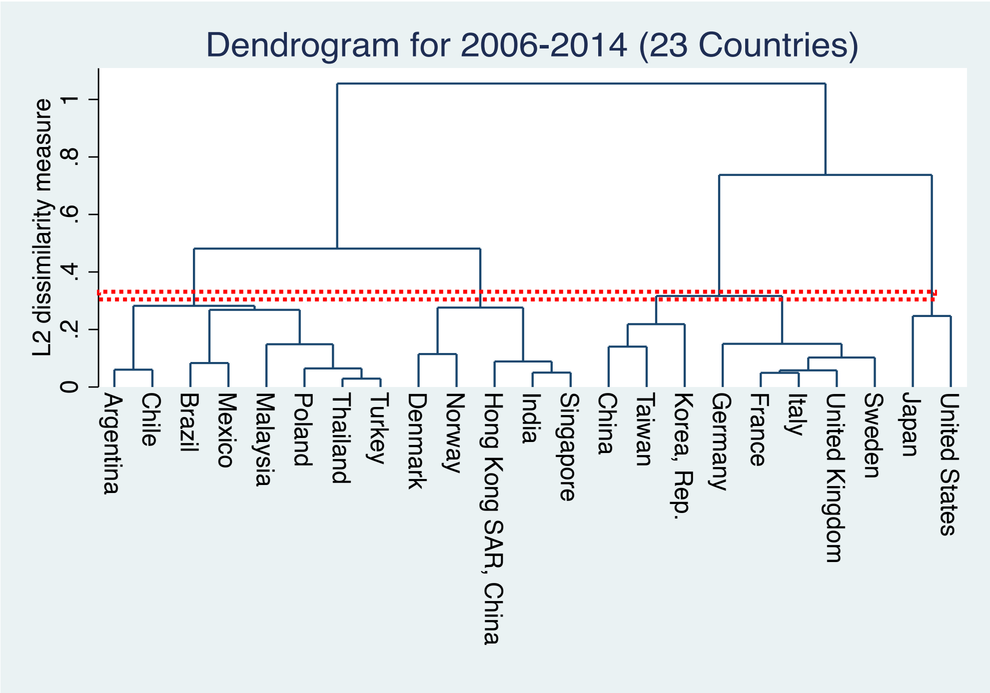
6.1 Cluster Analysis Results

This section presents the results of the clustering analysis. To demonstrate the robustness of the results, the core 23 countries are analyzed, and then 33 countries are analyzed. The core 23 countries include United States, Japan, Sweden, United Kingdom, Italy, France, South Korea, Taiwan, China, Singapore, India, Hong Kong, Norway, Denmark, Turkey, Thailand, Poland, Malaysia, Mexico, Brazil, Chile and Argentina. And then, Canada, Switzerland, Netherlands, Russia, Ireland, Israel, Spain, Greece, Portugal and South Africa are added in the analysis.

Figure 2A presents the dendrogram of the results of the hierarchical cluster analysis using the five NIS data for 2006-2014 period. The vertical axis in this analysis indicates the coefficient of dissimilarity among economies in different clusters. The clusters are consolidated at different stage. Then, the coefficient of dissimilarity tends to rise when the number of clusters decreases because dissimilar countries end up in the same cluster at the upper part of the graph.

Since single best rule has not been adopted to select a rational grouping[⑧], this paper sets at the 0.32 level of dissimilarity (red dotted lines in Figure 2A). At this level, 23 countries are classified into five clusters: outlier cluster (United States and Japan), a cluster of European developed countries (Sweden, United Kingdom, Italy, France, Germany), a cluster of East Asia Catching-up countries (S. Korea, Taiwan, China), a cluster including Singapore, India, Hong Kong, Norway, Denmark and a cluster including Turkey, Thailand, Poland, Malaysia, Mexico, Brazil, Chile and Argentina. Shown in Figure 2B, results of the clustering analysis using 33 countries remain same with five different clusters classified by the 0.33 level of dissimilarity.

Figure 2A. Dendrogram for 23 countries (2006-2014)



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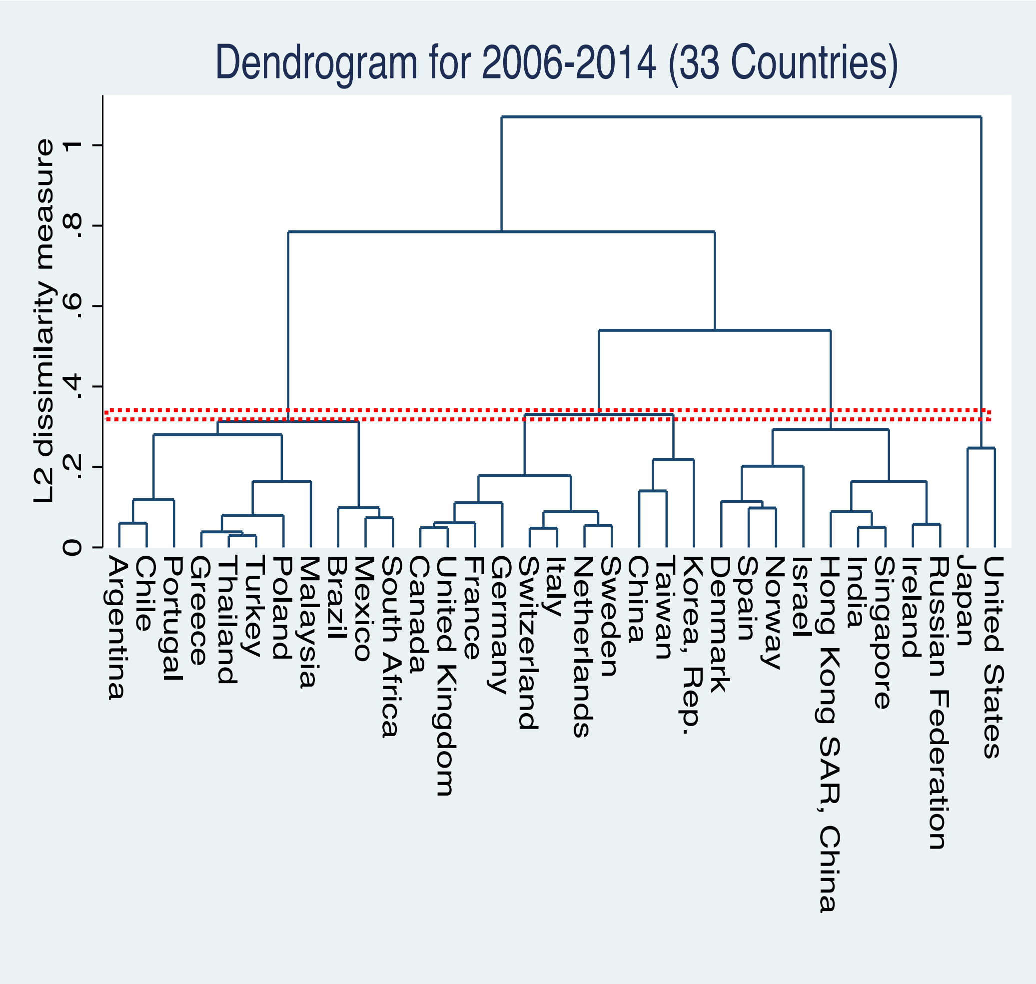
⑧ Milligan and Cooper (1985) considered 30 different methods for deciding on the number of clusters. One commonly used rule is the Calinski–Harabasz pseudo-F statistics, which measures the variation among clusters relative to the variation within such clusters. The study found that this rule often resulted in strange groupings that were contrary to prior knowledge.

Figure 2B. Dendrogram for 33 countries (2006-2014)



Note: 1) Balanced Mature: Sweden, Netherlands, Italy, Swiss, Germany, France, UK, Canada
2) Imbalanced Catching up: Korea, Taiwan, China
3) Balanced mixed: Russia, Ireland, Singapore, Hong Kong, India, Israel, Norway, Spain, Denmark
4) Imbalanced Mixed: Poland, Chile, Malaysia, Mexico, Brazil, Argentina, South Africa, Thailand, Portugal, Greece and Turkey

The characteristics of the clusters seem to be apparent by making radial graphs as Figure 3A, B and C. The value of the NIS variables in radial graphs are all normalized in order to consolidate the range from 0 to 1[⑨]. Figure 3A compares normalized NIS variables between balanced NIS clusters, i.e. the balanced mature cluster, the balanced

⑨ Normalized value A = (A − minimum values of A) / (maximum value of A − minimum value of A).

Mixed cluster and the balanced catching-up cluster. The balanced mature cluster refers to a cluster of Sweden, Netherlands, Italy, Switzerland, Germany, France, United Kingdom and Canada. The cluster has relatively similar (Coefficient of variance is 0.48) and high value of all five NIS variables. The balanced mixed cluster refers to a cluster of Singapore, India, Hong Kong, Norway, Denmark, Spain, Israel, Ireland and Russia, because the term mixed means that a cluster includes India aside from the high-income economies. This cluster also has a similar (0.62, Coefficient of variance) value of all five NIS variables. Lee and Lee (2019) coined the term the 'balanced Catching-up NIS' economies which focus on the service sector. The balanced catching-up cluster includes Singapore, Hong Kong, Ireland and Spain and has 0.66 as the coefficient of variance.

Figure 3B shows the radial graph of imbalanced NIS clusters, i.e. the imbalanced trapped, the imbalanced Catching-up and the imbalanced mixed. The imbalanced trapped refers to a cluster of economies failed to grow beyond the MIT and includes Mexico, Brazil, Argentina, South Africa and Thailand. This cluster shows a very imbalanced radial graph (0.7 Coefficient of variance), implying low levels of normalized diversification and localization NIS, and comparatively high levels of normalized relative cycle time of technology, decentralization and originality NIS. The imbalanced Catching-up indicates a cluster of East Asian catching-up economies (S. Korea, Taiwan and China) and has the highest value of coefficient of variation, 0.89. Characteristics of this cluster has low values of cycle time of technology and originality, and relatively high value of localization and diversification NIS.

Poland, Chile and Malaysia that have recently grown beyond the MIT can be classified into the imbalanced mixed cluster which has a high value of coefficient of variation, 0.75. Study of Chile and Malaysia analyzed by Lebdioui, Lee and Pietrobelli (2020) suggests that firms in the resource-based sector level close the technological gap with frontier capabilities. Meanwhile, Figure 3B captures that Poland has relatively low levels of normalized relative cycle time of technology, originality, localization and diversification NIS, and a high level of normalized decentralization NIS. It shows that Poland does not belongs to the NIS growth path type.

Figure 3A. Radial graph of Balanced Clusters (Mature, Catching-up and Mixed)

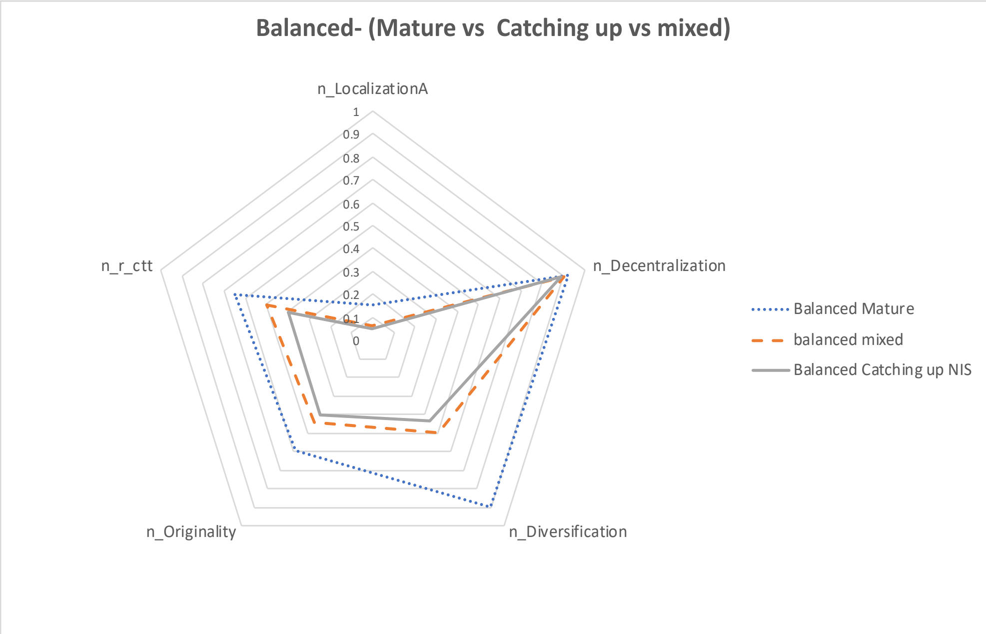
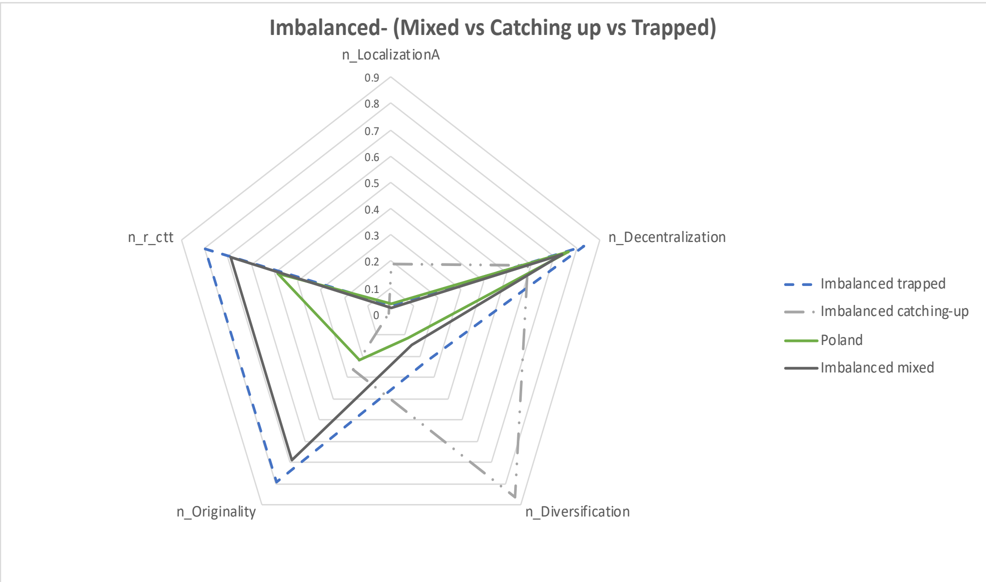


Figure 3B. Radial graph of Imbalanced clusters (trapped, Catching-up and mixed)



6.2 NIS comparison

Cycle time of technologies

Figure 4A and B shows trends of the relative cycle time of technology (CTT) from 1980 to 2019 using 4 period moving average value. The relative CTT for the imbalanced trapped has a long stagnant trend above 1 the relative CTT. The balanced mature has an increasing trend of the relative CTT from 0.92 to 1.02, which is consistent with the fact that advanced countries have developed technologies with long longevity such as pharmaceutical technology. The imbalanced catching-up shows the extremely interesting pattern of the relative CTT, which has much lower value of the CTT than any other clusters. A sustain decline of this variable since 1980 implies that the success of East Asian economies is positively correlated with specialization in the short cycle technology.

Compared to other trapped economies shown in Figure 4B, the trend of Poland is evident. Poland has experienced decreasing trend since 1999, whereas Brazil, Argentina, Mexico, South Africa have high values of the relative cycle, which exceed 1. Moreover, Poland reached 0.9085 relative CTT in 2008. A short CTT means that the country focuses on the short life span of the knowledge, which does less rely on old technology and does more opportunity for new technology. According to appendix Table1, Poland was not focused on the specific patent class in 1996, however, in 2008, it focused on Electric communication technique, and recently, in 2019 focused on Computing calculating class. A short CTT in these field of patents appears to promote Poland to achieve economic growth.

Figure 4A. The Relative cycle time of technologies

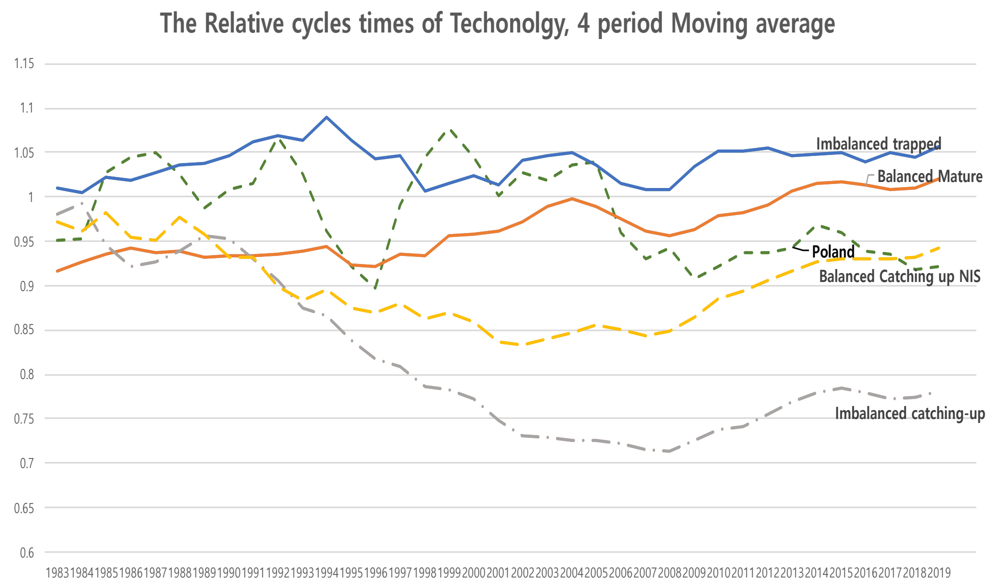
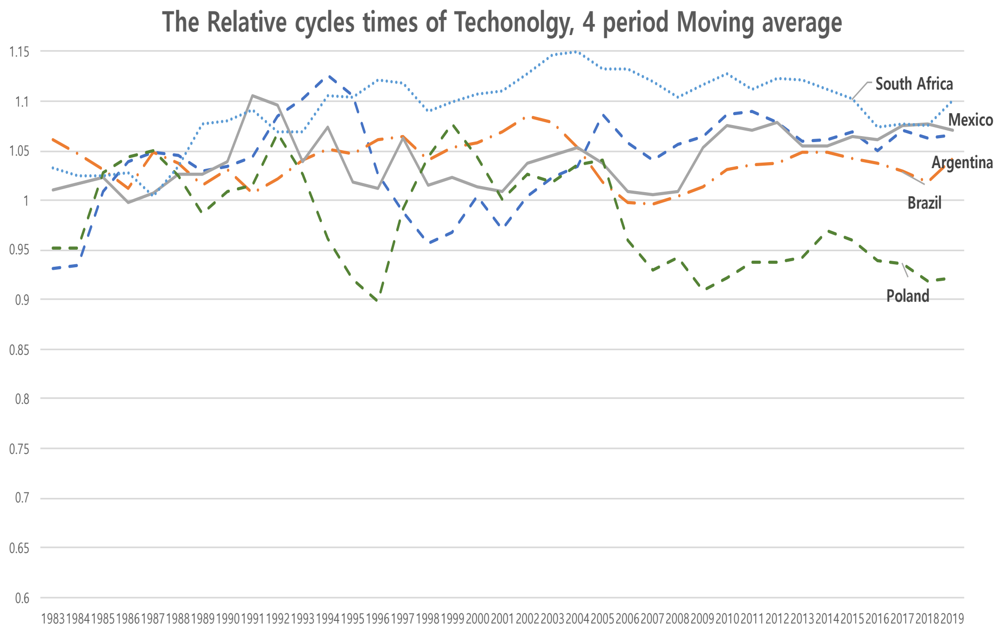


Figure 4B. The Relative cycle time of technologies



Knowledge localization

Figure 5A and B represents the localization NIS variable trends in cluster and country level respectively. Although the trend of the localization NIS for the balanced mature has a decreasing pattern, the value of the cluster remains higher than other clusters, except the imbalanced catching-up. The imbalanced catching-up has a steady and increasing trend of the localization of knowledge creation and diffusion since 1985 and overtakes the level of the balanced mature. Since the localization of knowledge creation and diffusion captures the extent to which patent citations are made within national boundaries, a finding is not surprising. Whereas the balanced catching-up, and the imbalanced trapped face long and low levels of localization trends.

As Figure 5B shows, Poland has experienced a low level of the localization NIS, albeit increases the value recently. Argentina, South Africa, Brazil and Mexico also do not demonstrate a similar catch-up as the imbalanced catching-up in terms of the localization of knowledge creation and diffusion. The decline trend during the 1980 in Argentina and Mexico coincides with the decline trend of the GDP per capita ratio to US per capita income.

Figure 5A. Localization

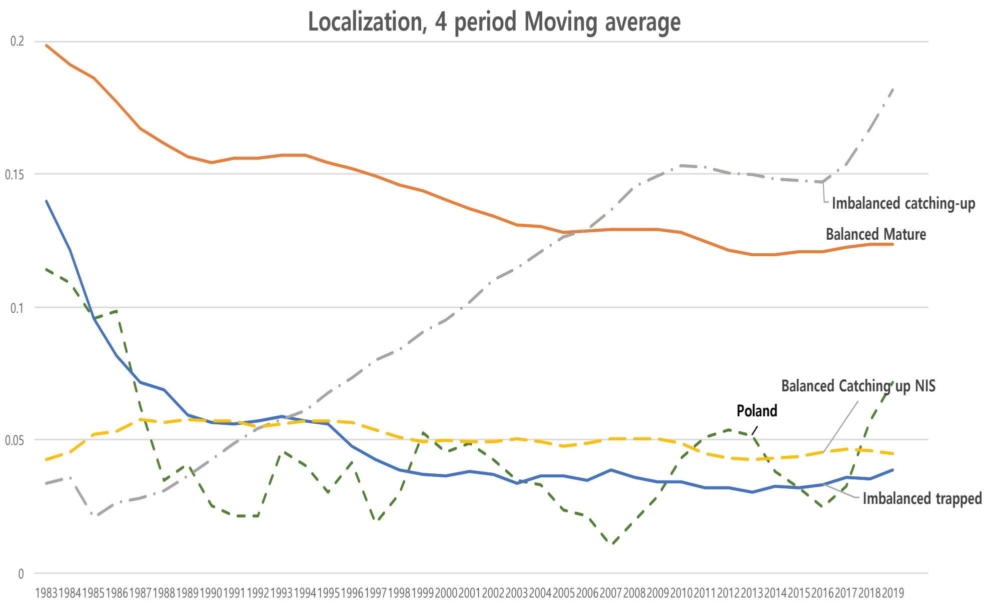
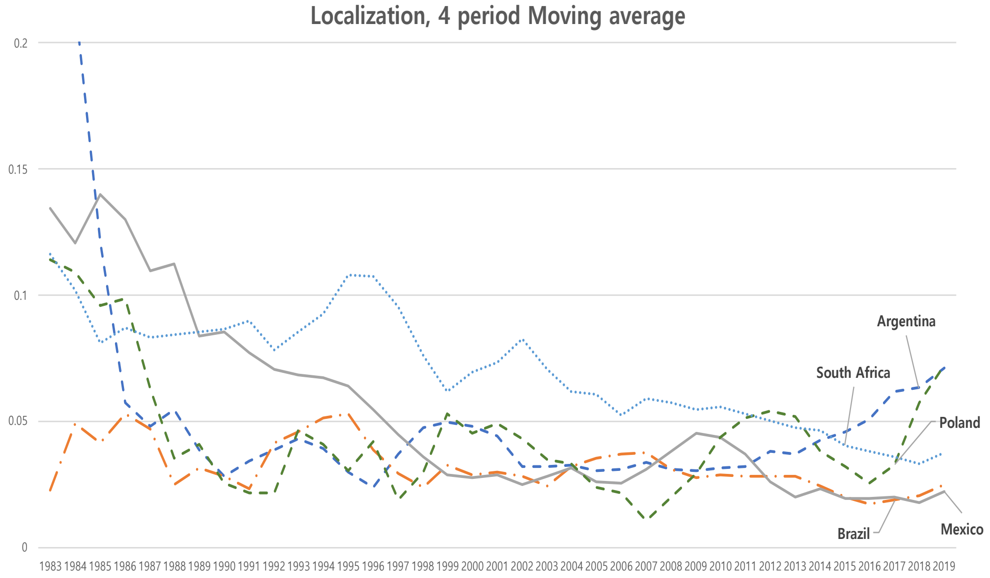


Figure 5B. Localization



Technological Diversification

Trends of the technological diversification NIS are presented in Figure 6A and B. The diversification for the balanced mature remains the highest level among clusters for 40 year. The imbalanced catching-up has steadily raised the diversification level since 1980 from 0.17 in 1983 to 0.85 in 2019 which is equivalent to the level of the balanced mature in 2019. The diversification for the balanced catching-up, and the imbalanced trapped have experienced the increasing trends, however, the value is much lower than that of the balanced mature or the imbalanced catching-up.

Poland have experienced a rapid increase in the diversification since 2010. However, shown in Figure 6A and B, the diversification level of Poland is lower than the level of the imbalanced trapped and the trapped economies like Brazil, Mexico and South Africa.

Figure 6A. Technological Diversification

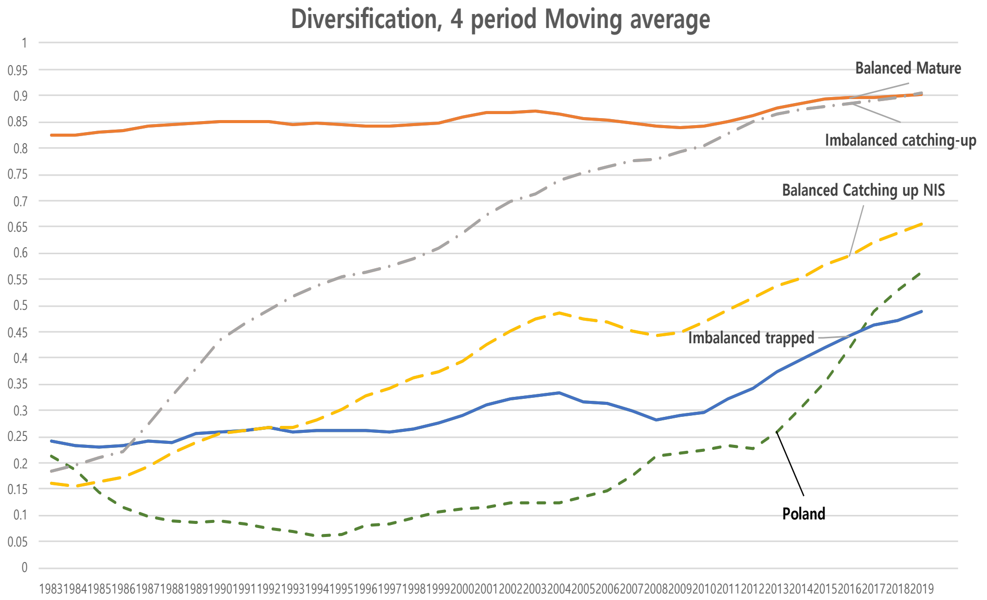
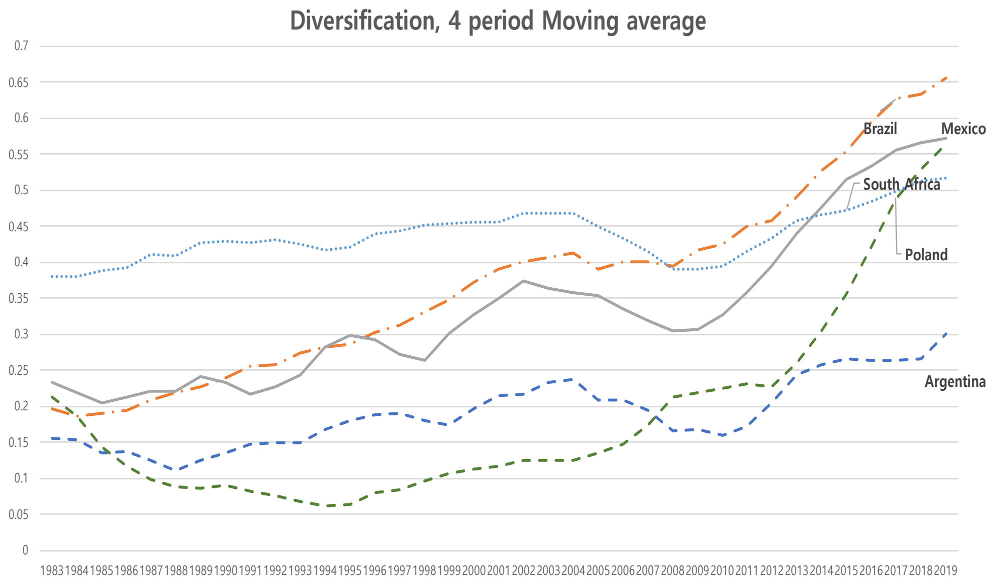


Figure 6B. Technological Diversification



Originality

Figure 7A and B show the patterns of the originality NIS. Although variations of the originality trend can be identified in all clusters in

Figure 7A, the originality trends share a long and steady increase pattern among the clusters. Figure 7B captures that the originality of Poland slightly lags behind Mexico, Brazil, South Africa and Argentina. This implies the originality has failed to bring a difference in NIS.

Figure 7A. Originality

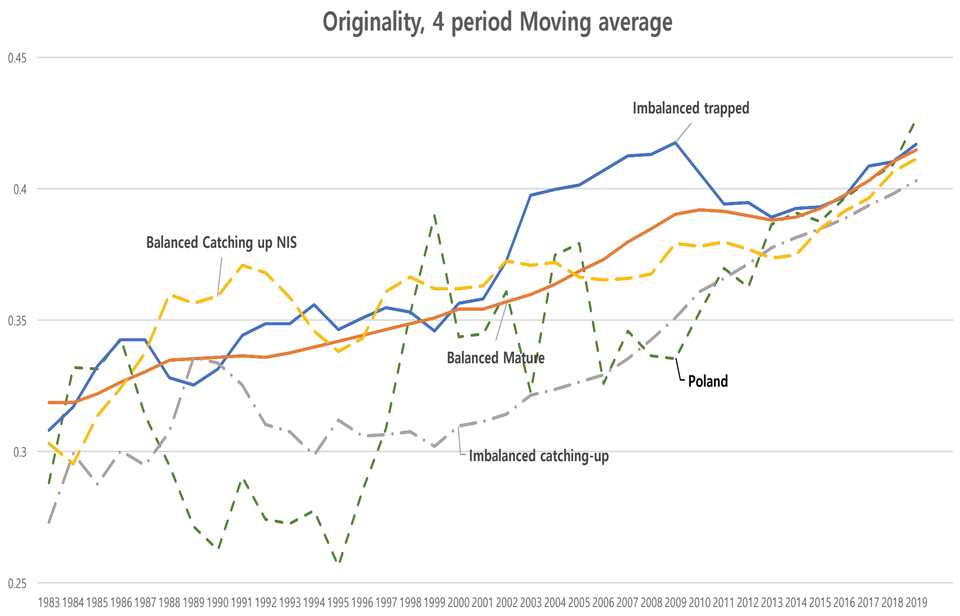
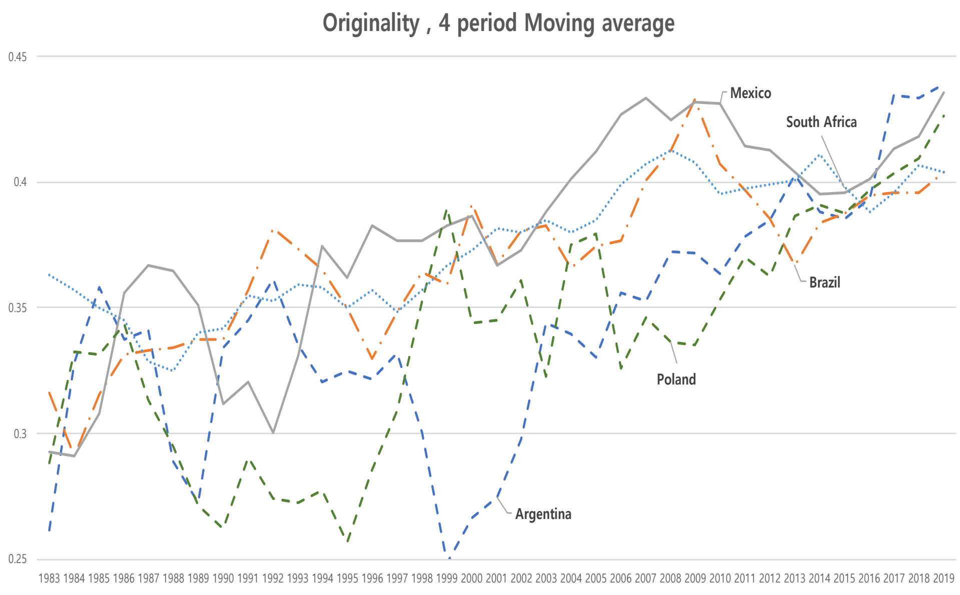


Figure 7B. Originality



Decentralization across the assignee

Figure 8A and B shows the trend of the decentralization NIS or inverse concentration across the assignee in the cluster and country level, respectively. The decentralization for the balanced mature remains the highest level for 40 years among the clusters. In contrast, the decentralization NIS for the imbalanced catching-up cluster shows the large discrepancy with the balanced mature in the late 1990. Moreover, the imbalanced catching-up has been lagged behind the imbalanced trapped since 2000. In contrast, in the balanced mature cluster, inventions are spread more widely among a larger number of assignees, wherein in the imbalanced catching, they are dominated by a smaller number of assignees.

Shown in Figure 8A, Poland has been improved in the decentralization NIS variables, compared to other clusters. However, Figure 8B shows that Poland has comparatively low values of the decentralization than other trapped economies, South Africa, Brazil, Argentina and Mexico. Brazil and Argentina show a high degree of decentralization, which is the same level as that of the balanced mature cluster. Thus, this finding represents the decentralization NIS cannot be the key engine for growth beyond middle-income trap.

Figure 8A. Decentralization

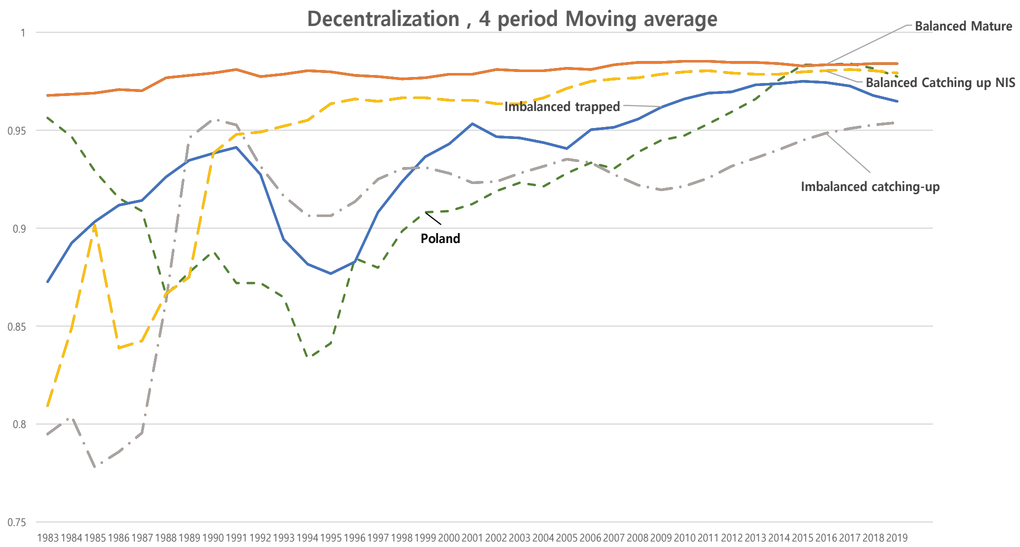
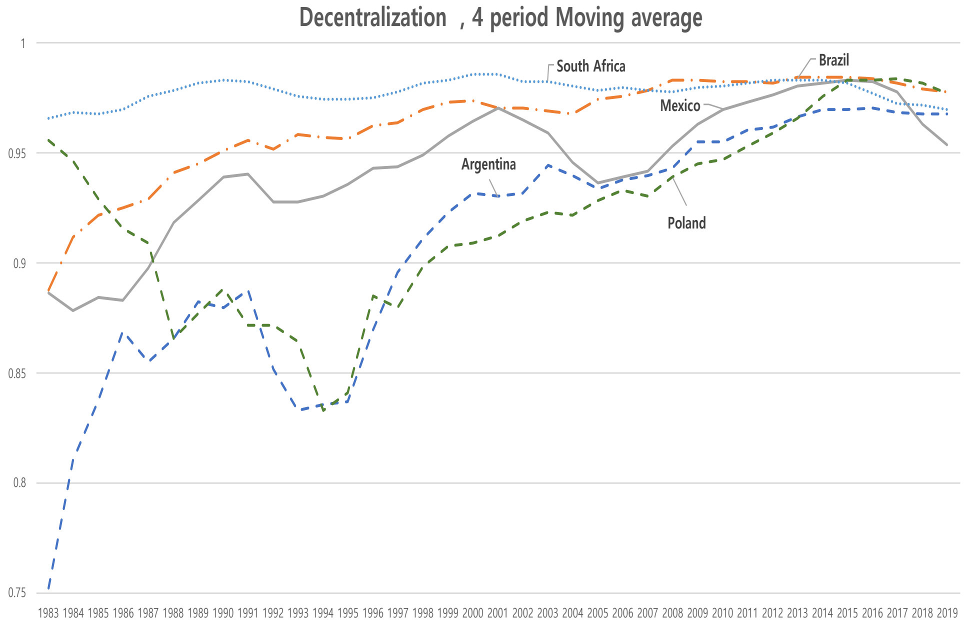


Figure 8B. Decentralization

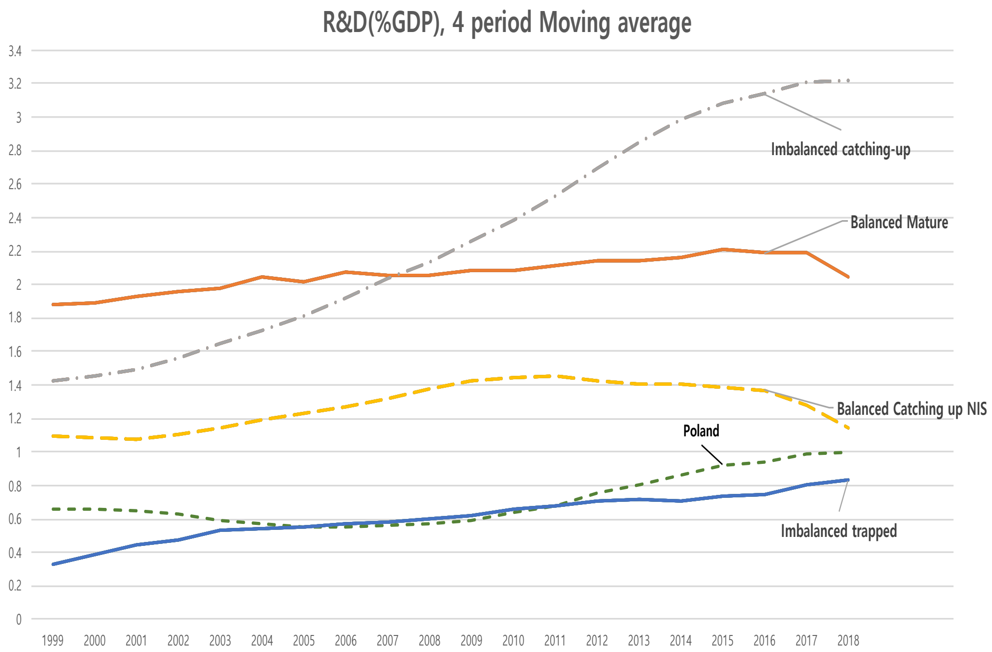


Research and Development (R&D)

Shown in Figure 9A, the research and development expenditure ratio for the imbalanced catching-up has surged from 1% in 1996 to 3.2% in 2018 and grown beyond the level of the balanced mature. The R&D ratio for the balanced mature sustains 2 percent of GDP, which is almost twice as large as the value for the imbalanced trapped. It can be identified in Figure 10A that all high-income clusters including the catching-up clusters and the mature cluster exceeds 1 percent of the R&D expenditure ratio to GDP. The R&D ratio seems to have positive relation with economic growth when the ratio exceeds the threshold, 1 percent to GDP.

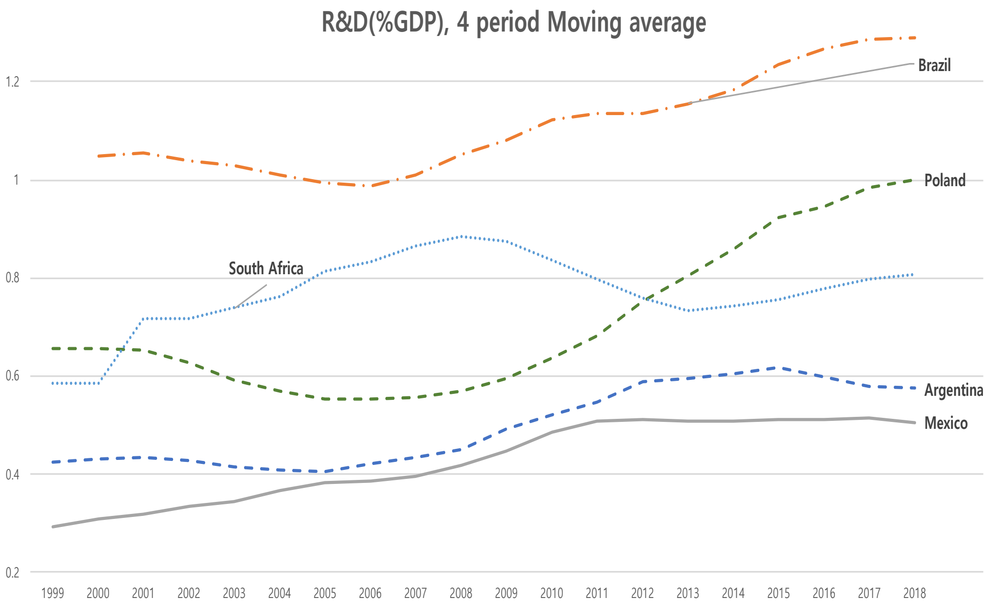
In Figure 9B, Poland has sustained small growth in the R&D ratio, which has exceeded 1 percent to GDP in 2019. Meanwhile, the trapped economies such as South Africa, Argentina and Mexico have no increase in the variable. However, Brazil exceeds the threshold ratio. R&D expenditure alone appears to not have the positive influence on economic growth.

Figure 9A. R&D Expenditure Ratio to GDP



Source: World Bank database and Taiwan Statistics authorities

Figure 9B. R&D Expenditure Ratio to GDP



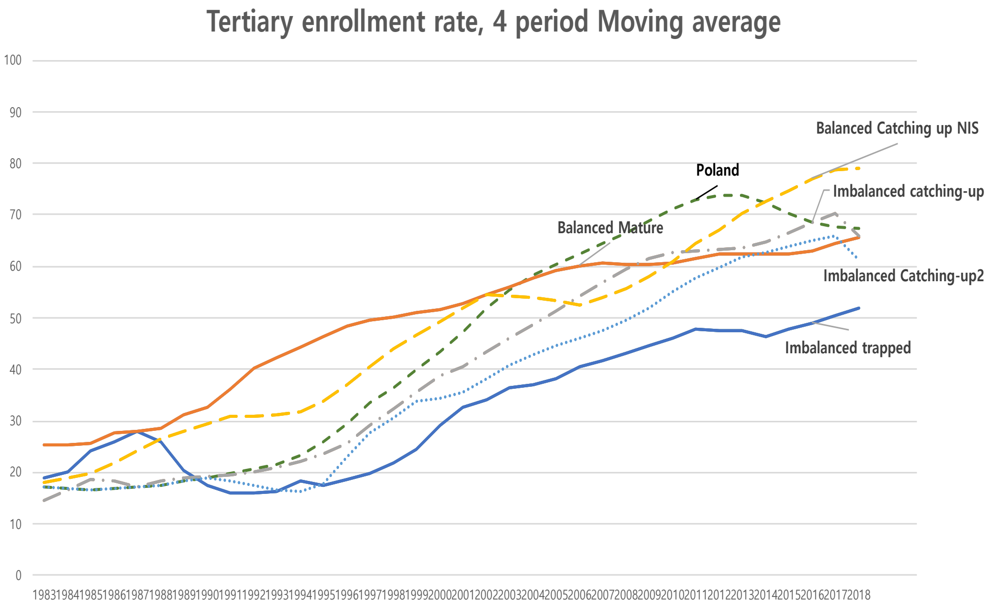
Source: World Bank database and Taiwan Statistics authorities

Tertiary enrollment ratio

Figure 10A presents the tertiary enrollment ratio as NIS variable. The balanced mature has sustained increasing trend of the tertiary ratio from 26% in 1993 to 65% in 2018, whereas the imbalanced trapped has increased the rate by 30% to 52% in 2018. The balanced catching-up has reached 80% in 2018. The imbalanced catching-up clusters also has exceeded 65% of the enrollment ratio since 2017. The imbalanced trapped lags behind by 30% compared to the balanced catching-up in 2015. Poland's the tertiary enrollment ratio has been surged from less than 20% before 1995 to 75% in 2011 and surpassed other clusters.

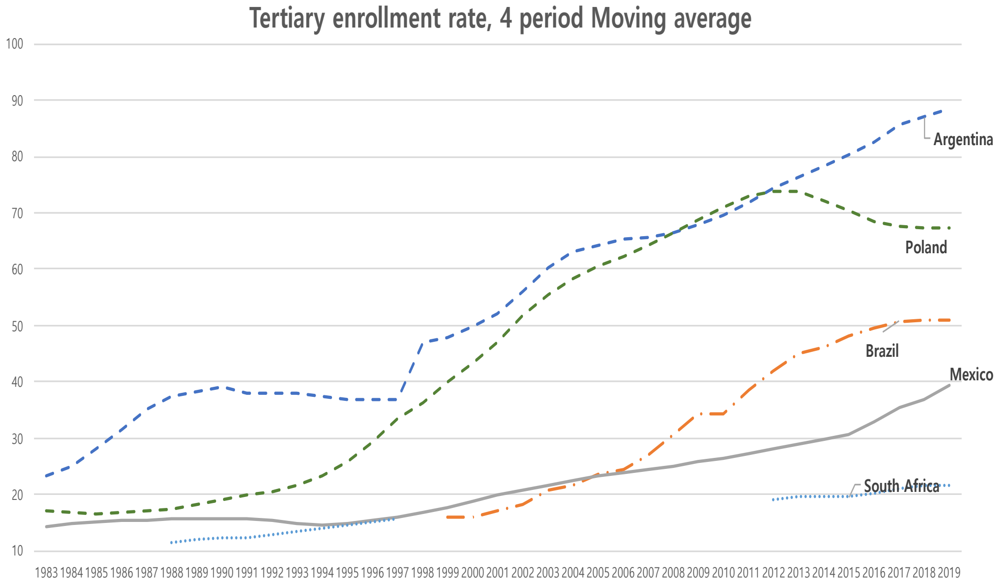
Poland has experienced a rapid increase in the tertiary enrollment rate variable, whereas shown in Figure 10B, the enrollment rates for Brazil, Mexico and South Africa are below than 51%. However, Argentina has an increasing trend of the tertiary rate to 88% in 2018. Then, it may interpret that this variable alone cannot be used as the indicator of economic growth.

Figure 10A. Tertiary Enrollment Ratio



Source: World Bank database

Figure 10B. Tertiary Enrollment Ratio



Source: World Bank database

Chapter 7.
Data Envelopment Analysis Result

This section shows the result of DEA. Because of the missing data issue in R&D expenditure and the tertiary enrollment rate, this study selects 26 countries to measure the efficiency of NIS variables on the total factor productivity growth rate. For consistency in the calculation of TFP, TFP at constant national prices data of Penn World Table 9.1 was used (Feenstra, Inklaar and Timmer, 2015). The data from 1999 to 2008 were used to measure the efficiency of Poland's transition from a middle-income country to a high-income country of more than 40 percent of the per capita income of the United States. Table 3 shows the average value of seven NIS variables during the period and the relative efficiency indicators as results of the DEA.

Both input oriented and output oriented methods show robust relative efficiency results. If a value of output oriented CCR efficiency is 1, a DMU, one of selected countries, is efficient, while more than a value of 1 indicates that a DMU is inefficient. Hong Kong, for instance, has a score of 1.671, which means that it should be possible to increase the TFP growth rate by 67% with the same level of inputs. If a value of input oriented CCR efficiency is 1, a country is efficient; less than a value of 1 means a country is inefficient. For example, South Korea could reduce the NIS input variables by 2.1%, and produce the same level of the TFP growth. As Table 3 shows, high-income countries with slower economic growth have resulted in relative low efficiency rates. Other trapped countries, Argentina, Brazil, and Mexico have also low levels of the relative efficiency rate. While both Malaysia and Chile follow the resource-based growth path, Malaysia uses NIS for TFP growth efficiently, however, Chile faces the negative TFP growth rate. Poland, China, and Malaysia belong to the efficient frontier, followed by Russia and South Korea. Thus, it can be inferred that Poland sought the efficient use of NIS variables in the growth of TFP.

Table 3. DEA results (1999-2008 average)

DMU	Localization	Relative CTT	Diversification	Decentralization	Originality	RD	tertiary	TFP growth rate	CCR_eff_Input	CCR_eff_Output
China	0.042	0.781	0.573	0.966	0.370	1.147	15.006	2.914	1.000	1.000
Malaysia	0.021	0.796	0.255	0.917	0.384	0.624	28.108	2.049	1.000	1.000
Poland	0.032	0.986	0.162	0.930	0.349	0.587	59.420	1.583	1.000	1.000
Russian Federation	0.041	1.015	0.463	0.986	0.372	1.121	67.165	2.553	0.981	1.019
Korea, Rep.	0.135	0.705	0.818	0.831	0.291	2.533	87.733	2.240	0.979	1.021
Greece	0.015	0.997	0.139	0.908	0.345	0.573	69.907	0.699	0.599	1.671
Hong Kong SAR, China	0.092	0.812	0.476	0.989	0.451	0.669	38.342	1.182	0.551	1.814
Sweden	0.111	0.983	0.793	0.975	0.336	3.493	74.821	1.228	0.464	2.157
India	0.035	0.899	0.371	0.928	0.356	0.771	11.253	0.772	0.398	2.515
United Kingdom	0.092	0.974	0.904	0.996	0.370	1.603	59.498	0.791	0.272	3.681
United States	0.738	0.893	0.940	0.997	0.391	2.593	78.026	0.771	0.257	3.896
Israel	0.063	0.882	0.713	0.992	0.363	4.033	56.201	0.590	0.207	4.839
Netherlands	0.090	0.948	0.775	0.930	0.417	1.753	56.282	0.552	0.197	5.076
Argentina	0.032	1.040	0.203	0.939	0.337	0.432	62.062	0.279	0.196	5.092
Switzerland	0.132	1.012	0.813	0.993	0.358	2.570	43.355	0.541	0.192	5.202
Ireland	0.036	0.889	0.355	0.974	0.349	1.166	54.536	0.261	0.118	8.488
France	0.152	0.966	0.899	0.993	0.360	2.092	52.175	0.333	0.117	8.517
Canada	0.106	0.949	0.896	0.994	0.385	1.930	61.256	0.096	0.032	31.111
Brazil	0.030	1.035	0.404	0.975	0.395	1.031	25.557	0.004	0.002	632.200
Chile	0.043	1.038	0.143	0.901	0.428	0.342	50.444	-0.626	0.000	
Denmark	0.082	1.026	0.626	0.969	0.423	2.434	69.207	-0.090	0.000	
Spain	0.042	0.964	0.566	0.984	0.365	1.046	63.837	-0.578	0.000	
Italy	0.149	0.968	0.843	0.987	0.373	1.066	59.129	-0.786	0.000	
Mexico	0.031	1.030	0.340	0.955	0.406	0.377	23.022	-0.958	0.000	
Norway	0.054	1.083	0.546	0.986	0.374	1.564	74.176	-0.299	0.000	
Portugal	0.015	1.036	0.103	0.859	0.377	0.860	53.707	-0.222	0.000	

Chapter 8.
Concluding Remarks

This paper first uses five national innovation system variables, i.e. the relative cycle time of technology, the localization, the originality, the decentralization and the diversification of knowledge to carry out clustering analysis and compares the performance of 33 selected economies. The clustering analysis identifies not only several types of economies such as the balanced mature, the imbalanced mixed and the imbalanced trapped, but also confirms catching-up NIS clusters which succeed in growth beyond MIT. The analysis identifies the uniqueness of Poland economic growth in the sense that it does not belongs to existing catching-up NIS types.

Unlike two pathways to catch up from middle-income countries to high-income, Poland has relatively low levels of relative cycle time of technology, originality, localization and diversification NIS, and a high level of decentralization NIS. As the granted Polish patent of U.S. patent data is concentrated on the electric communication technique class, Poland has focused on the short cycle technology. Moreover, R&D expenditure (%GDP) and the tertiary education enrollment rate have been increased. Poland has a steady increasing trend of tertiary enrollment rate 75% in 2012, and it exceeds 1% of GDP as R&D expenditure.

From 1996 to 2008, Poland's economic growth beyond the MIT was not explained in much part by the accumulation of capital and labor. Studies of total factor productivity, unexplained part of the growth, have rarely addressed the national innovation system. In this study, Data envelopment analysis measures the efficiency of seven NIS variables which additionally include R&D expenditure (%GDP) and the tertiary education enrollment rate on the TFP growth. Both input oriented and output oriented CCR model indicate that already high-income economies such as U.K., U.S., and Netherlands have moderate relative efficiency. And trapped countries show relatively inefficient use of NIS variables. Mexico has a negative TFP growth rate. On the other hand, Poland, China and Malaysia use the national innovation system most efficiently among selected sample countries. It can be argued that Poland has efficiently used the national innovation system in the growth of total factor productivity.

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Appendix Table 1. Poland's major classification of Patent

Year	CPC	percent	Class
1996	F16	13.33333	ENGINEERING ELEMENTS AND UNITS; GENERAL MEASURES FOR PRODUCING AND MAINTAINING EFFECTIVE FUNCTIONING OF MACHINES OR INSTALLATIONS; THERMAL INSULATION IN GENERAL
1996	C07	13.33333	Organic Chemistry
1996	A61	13.33333	Medical or Veterinary Science; Hygiene
1997	C07	18.18182	Organic Chemistry
1997	H01	18.18182	Basic Electric elements
1997	A61	27.27273	Medical or Veterinary Science; Hygiene
1998	A61	13.33333	Medical or Veterinary Science; Hygiene
1998	G01	13.33333	Measuring; Testing
1998	B21	13.33333	MECHANICAL METAL-WORKING WITHOUT ESSENTIALLY REMOVING MATERIAL; PUNCHING METAL
1998	C08	20	ORGANIC MACROMOLECULAR COMPOUNDS; THEIR PREPARATION OR CHEMICAL WORKING-UP; COMPOSITIONS BASED THEREON
1999	A61	15.78947	Medical or Veterinary Science; Hygiene
1999	C07	42.10526	Organic Chemistry
2000	G01	15.38461	Measuring; Testing
2000	A61	23.07692	Medical or Veterinary Science; Hygiene
2001	H05	12.5	ELECTRIC TECHNIQUES NOT OTHERWISE PROVIDED FOR
2001	A61	37.5	Medical or Veterinary Science; Hygiene
2002	C07	18.18182	Organic Chemistry
2003	A61	23.52941	Medical or Veterinary Science; Hygiene
2004	A61	12.5	Medical or Veterinary Science; Hygiene
2004	G01	18.75	Measuring; Testing
2004	H01	18.75	Basic Electric elements
2005	F16	13.04348	ENGINEERING ELEMENTS AND UNITS; GENERAL MEASURES FOR PRODUCING AND MAINTAINING EFFECTIVE FUNCTIONING OF MACHINES OR INSTALLATIONS; THERMAL INSULATION IN GENERAL
2005	C07	13.04348	Organic Chemistry
2005	H04	17.3913	ELECTRIC COMMUNICATION TECHNIQUE
2006	G01	10.34483	Measuring; Testing
2006	H04	10.34483	ELECTRIC COMMUNICATION TECHNIQUE
2006	C30	10.34483	CRYSTAL GROWTH
2006	G06	13.7931	COMPUTING; CALCULATING; COUNTING
2007	C07	12.5	Organic Chemistry
2007	H04	18.75	ELECTRIC COMMUNICATION TECHNIQUE
2008	H04	12.96296	ELECTRIC COMMUNICATION TECHNIQUE
2008	C30	16.66667	CRYSTAL GROWTH
2009	H01	11.42857	Basic Electric elements

2009	H04	20	ELECTRIC COMMUNICATION TECHNIQUE
2010	G06	10.25641	COMPUTING; CALCULATING; COUNTING
2010	C07	12.82051	Organic Chemistry
2010	H04	17.94872	ELECTRIC COMMUNICATION TECHNIQUE
2011	A61	10.52632	Medical or Veterinary Science; Hygiene
2011	C07	14.03509	Organic Chemistry
2012	G01	11.68831	Measuring; Testing
2012	A61	12.98701	Medical or Veterinary Science; Hygiene
2012	H04	12.98701	ELECTRIC COMMUNICATION TECHNIQUE
2012	G06	14.28571	COMPUTING; CALCULATING; COUNTING
2013	H04	10.6383	ELECTRIC COMMUNICATION TECHNIQUE
2013	C07	15.95745	Organic Chemistry
2013	G06	18.08511	COMPUTING; CALCULATING; COUNTING
2014	H04	10.49383	ELECTRIC COMMUNICATION TECHNIQUE
2014	G06	18.51852	COMPUTING; CALCULATING; COUNTING
2015	G06	16	COMPUTING; CALCULATING; COUNTING
2016	H04	12.5	ELECTRIC COMMUNICATION TECHNIQUE
2016	G06	18.30357	COMPUTING; CALCULATING; COUNTING
2017	H04	15.44402	ELECTRIC COMMUNICATION TECHNIQUE
2017	G06	20.84942	COMPUTING; CALCULATING; COUNTING
2018	H04	20.23809	ELECTRIC COMMUNICATION TECHNIQUE
2018	G06	22.22222	COMPUTING; CALCULATING; COUNTING
2019	H04	11.51515	ELECTRIC COMMUNICATION TECHNIQUE
2019	G06	21.21212	COMPUTING; CALCULATING; COUNTING

초 록

중진국 함정(Middle-income trap)은 국가의 1인당 GDP가 미국 1인당 GDP의 20%~40%수준인 것을 의미한다. 폴란드는 2008년에 IMF 구매력평가지수(PPP)를 기준으로 1인당 GDP가 미국 1인당 GDP의 40%를 넘어서면서 1960년 이후 중진국 함정을 극복한 몇 안되는 국가들 중에 하나가 됐다.

이 논문은 33개국의 미국 특허청 등록 특허 (Granted Patent)를 분석하여, 이들 국가별 국가혁신체계 (National Innovation System)를 비교한다. 먼저, 국가혁신체계를 나타내는 다섯 개 변수, 즉, 지식의 현지화 (the Knowledge Localization), 기술의 생명 주기 (the Cycle Time of Technologies), 지식의 독창성 (the Originality), 지식의 다각화 (the Diversification), 그리고 지식의 분권화 (the Decentralization)를 이용해 폴란드가 어떤 성장 경로와 유사한 지 군집화 분석을 진행한 결과, 기존 알려진 성장 경로와는 다른 모습을 보여줬다.

또한, 1996년부터 2008년까지 이뤄진 폴란드의 급속한 경제성장은 자본과 노동의 축적보다는 총요소생산성의 두드러진 성장에서 기인한 것으로 확인되었다. 이에 자료포락분석법을 사용해 국가혁신체계가 총요소생산성 성장에 얼마나 효율적으로 작용하였는지 비교 분석을 진행하였다. 1999년부터 2008년까지의 평균치를 분석한 결과, 비교대상국들 중 폴란드가 가장 효율적으로 국가혁신체계를 활용해 총요소생산성의 성장을 이끌어 냈다는 결과가 도출되었다.

주요어 : 군집화 분석; 자료포락분석법; 중진국 함정; 국가혁신체계; 특허 분석; 경제 성장

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