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Byeongwoo KANG*, Kaoru NABESHIMA†, and
Fang-Ting CHENG‡

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Abstract

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Keywords: middle income trap, innovation, duration model

JEL classification: O40, O30, C41

* Research Fellow, Inter-disciplinary Studies Center, IDE (Byeongwoo_Kang@ide.go.jp)

† Chief Senior Researcher, Inter-disciplinary Studies Center, IDE (kaoru_nabeshima@ide.go.jp)

‡ Research Fellow, Inter-disciplinary Studies Center, IDE (Fangting_Cheng@ide.go.jp)

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INSTITUTE OF DEVELOPING ECONOMIES (IDE), JETRO
3-2-2, WAKABA, MIHAMA-KU, CHIBA-SHI
CHIBA 261-8545, JAPAN

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Byeongwoo Kang, Kaoru Nabeshima, and Fang-Ting Cheng

Byeongwoo_Kang@ide.go.jp, Kaoru_Nabeshima@ide.go.jp, Fangting_Cheng@ide.go.jp

Inter-disciplinary Studies Center, Institute of Developing Economies (IDE-JETRO)
Wakaba 3-2-2, Mihamaku, Chiba city, Chiba prefecture, 261-8545, Japan

Abstract: This paper investigates how innovation potential of a country contributes to avoid or escape the middle income trap. We measure innovation potentials of 77 countries from 1975 to 2010 from patent data. Then, we test whether indigenous innovative efforts or foreign ones help avoid and escape middle income traps.

Keywords: Economic growth; Innovative potential; Middle income trap; Patent data

1. Introduction

Differences in growth performance have been a popular subject of research in the economics. In particular, the question on why some countries can maintain their growth performance consistently for a long period of time to transition from low to high income countries, others fail to do so. Along the same line of thought, the middle income trap has attracted attention recently (Eichengreen, Park and Shin 2012;Felipe 2012;Ohno 2009;Paus 2012;Yusuf and Nabeshima 2009a;b). Although the middle income trap is not clearly defined, in general, the middle income trap is a situation where a country experiences slowdown in its economic growth once it achieves a middle income status and stays in that income range for a long time. The underlying reasons for this is believed to be an inability to transition from a growth model based on mass production with low-cost labor to products and services with higher value-addition through the extensive use of skills and technologies. The key to escape from the middle income trap seems to lie in innovation capabilities in a country.

This study focuses on a country's innovation potential and analyzes how innovation potential in a country contributed to avoid or escape the middle income trap. The research question in this paper is whether innovative potential affects economic growth and transition from one income categories to the other. A country's innovation potential in this paper is measured by patent data which contain technological knowledge. What differentiates our paper from previous studies using patent data is that our focus is not only on the number of patents (or a number of firms with patents) but also on the number of inventors. A study based on the patents is basically measuring the innovation "outcomes". What we are focusing here is on innovation "potential" which is better measured by the number of inventors which reflects the availability of human capital. We use the data on the availability of inventors within a country[1] and investigate how such domestic innovation capabilities are nurtured by domestic and foreign firms.

This paper makes two contributions to the field. First, this study covers many countries and compares their innovation potentials. There have been studies that measure and compare innovation potentials (Furman, Porter and Stern 2002;Hu and Mathews 2005) and technological capabilities (Lall 1992) between countries. However, much of the prior literature has neglected the need for technological activity in the developing countries and limited focus on the developed countries and a specific region. Second, this paper finds links between innovative efforts and economic growth. A group of studies (Fu and Gong 2011;Fu, Pietrobelli and Soete 2011;Li 2011;Sasidharan and Kathuria 2011) compared indigenous and foreign innovative efforts in technological capability. However, those studies did not provide whether either of indigenous or foreign innovative efforts or both of them contributes to economic growth and leading to avoidance of middle income traps. This paper further extends prior discussion by linking the interplay of indigenous and foreign innovative efforts to economic growth.

The structure of this paper is as follows. The next section reviews prior literature on the middle income trap and determinants of economic growth. Then, we formulate related hypotheses in Section 3. Section 4 explains data used in this study. In Section 5, we discuss the results of our analysis and verify the hypotheses formulated in Section 3. Section 6 concludes with remarks on policy implications and future research agendas.

[1] Although the nature of the data restrict us to define nationality based on the residential address. However, for our purpose this is appropriate since what we want to measure is a pool of skilled workers within a country regardless of their national origin.

2. Literature Review

2.1. Middle income trap

The World Bank defines four income levels by gross national income (GNI) per capita: low income, lower-middle income, upper-middle income, and high income economies. As of 1 July 2013, the World Bank income classifications by GNI per capita are as follows: 1) low income is up to $1,035, 2) lower-middle income is between $1,036 and $4,085, 3) upper middle income is between $4,086 and $12,615, and 4) high income is above $12,615. If anything, low and middle income economies are developing economies, and high income economies are developed economies. The World Bank income classification is the most widely used one to define the income level of a country.

Felipe (2012) examined in a comprehensive manner about the middle income trap. He defined the middle income trap in the absolute value point of view. Using per capita income data from 1950 to 2010, he classified 124 countries into four income groups based on gross domestic product (GDP) per capita in 1990 PPP dollars: 1) low income is up to $2,000, 2) lower-middle income is between $2,000 and $7,250, 3) upper-middle income is between $7,250 and $11,750, and 4) high income is above $11,750. Based on the income level classification, the authors defined that a country trapped in a lower-middle income trap if the per capita income of the country has stayed in the lower-middle income group for more than 28 years, and a country is trapped in upper-middle income trap if the per capita income of the country has stayed in the lower-middle income group for more than 14 years. To avoid the lower-middle income and the upper-middle income traps, a country has to achieve growth rates of 4.7 per cent and 3.5 per cent on average, respectively. He suggests that a country should develop more diversified, sophisticated, and non-standard export baskets in order to escape from the middle income trap.

Although the middle income trap is defined in different ways, the concept of middle income trap also has been widely appeared in other studies. Eichengreen, Park and Shin (2012) used the term to conceptualize a situation where a country faces a significant slowdown in economic growth. Ohno (2009) defined the five stages of catching-up industrialization for a country to achieve economic growth and used the middle income trap as the invisible glass ceiling between the second and the third stages. Paus (2012) used the middle income trap as a conceptual situation where a middle income country cannot compete with low wage countries in the export of standardized products on the one hand, but has not developed the capabilities to compete in the exports of skill and knowledge-intensive goods and services on the other.

2.2. Innovation potential for economic growth

Innovation is regarded as the key driver of economic development (World Bank 2010). There have been studies to measure a country's innovation potential. A study by Furman, Porter and Stern (2002) defined national innovative capacity as a country's potential to produce a stream of commercially relevant innovations. A country with high national innovative capacity can produce and commercialize a flow of new-to-the world technologies over the long term more than one with low national innovative capacity. Thus, innovative potential is a key for the long-term economic growth. However, much of the prior literature has neglected the need for innovation potential in the developing countries and limited focus on the developed countries and a specific region (Furman, Porter and Stern 2002;Hu and Mathews 2005).

Technology plays a key role in managing innovation. Innovation is a successful commercialization of new idea. However, ideas do not stand alone and they have to be realized as products and systems to provide economic benefits. Technology is a way to realize idea to a tangible form. Technology is often newly invented to play such a role. Sometimes, conventional technology is applied to a new field and is recombined with other technology to introduce new idea. Thus, managing innovation is largely about how to develop and exploit technological capability.

Among determinants of economic growth, technological capability is a key to the long-term economic growth. There have been many papers about technological capability development as a process of economic growth. Although details are different in each model, each model explains that a country moves from full reliance on foreign advanced knowledge to reliance more on indigenous knowledge. A classic model proposed by Kim (1980) specifies three stages; technology import/implementation, assimilation, and improvement. The model explains that even if a country begins its industrialization with full reliance on foreign advanced technology, technological knowledge accrues in the country because of the nature of learning-by-doing. At some point, innovative actors in the country try to imitate advanced technology from abroad and eventually to further develop the technology by themselves. On the other hand, a recent model by Ohno (2009) defines five stages from Stage zero to Stage four. A country starts from the stage zero where the economic structure is still fragile due to a war, political instability, and so on. After such severe economic mismanagement is removed, a country enters the stage one where manufacturing firms from abroad starts simple assembly production. A country enters the stage two where the domestic supply of parts and components begins to increase. A country is in the stage three when locals replace foreigners in all areas of production including management, technology, design, factory operation, logistics, quality control, and marketing. In the stage four, a country leads global market trends.

2.3. Indigenous innovative efforts v.s. foreign innovative efforts

A bundle of recent studies (Fu and Gong 2011;Fu, Pietrobelli and Soete 2011;Li 2011;Sasidharan and Kathuria 2011) discussed whether indigenous innovation efforts and those induced by foreign ones are supplementary or complementary. Foreign direct investment (FDI) has long been considered an important channel of technology transfer from developed to developing countries[2] and correlates to economic growth of developing countries. On the one hand, inflow of FDI also provides incentives to domestic firms to innovate in order to survive in severe competition with foreign firms with advanced technologies (assuming that these FDI firms are allowed to sell in the domestic market). On the other hand, inflow of FDI can lead to exit of young and uncompetitive domestic firms. The effect of technology spillover stemming from FDI is sometimes questioned because there is no incentive for foreign firms with advanced technologies to transfer core technologies to other firms. As a result, merely investing in FDI does not automatically lead to enhanced innovation capabilities. Furthermore, utilization of external knowledge requires absorptive capacity, the ability to recognize the value of new, external information, assimilate it and apply it to commercial ends (Cohen and Levinthal 1990), and indigenous efforts is necessary to acquire the absorptive capacity. Thus, indigenous innovative efforts must come together to make the best use of FDI, and indigenous and foreign innovative efforts complement each other.

3. Hypothesis

As suggested by Felipe (2012), we assume that there are two middle income traps, lower-middle income trap and upper-middle income trap. Accordingly we postulate that strategies to avoid or escape the lower-middle income trap and the upper-middle income trap are different. Sometimes the classification of middle-income country is confusing because the classification is artificial and hence it does not necessarily reflect economic, political, or social issues that countries in each middle income commonly encounter (UNDP, MOFA and KIEP 2013). Nonetheless, countries in each income level encounter similar development challenges, and grouping countries eases analysis and policy setting.

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[2] For an overview of various channels for technology transfer, see Nabeshima (2004). For the role of FDI in technology transfer, see Saggi (2006) and Smeets (2008).

As explained in Section 2, innovation potential is relevant to technological capability and necessary technological capability in each phase of economic growth is different. At an early stage of economic development, a country may heavily rely on foreign efforts. First, FDI is a way to absorb foreign advanced knowledge. With the entry of foreign advanced knowledge, human resources in developing countries have opportunities to observe advanced knowledge. Sometimes, training programs are managed by foreign firms to adjust output quality. Such foreign firms' efforts for technology transfer provide opportunities for human resources in developing countries to accrue technological capability by learning-by-doing and training programs. Second, even if a middle income country has some extent of technological capability, domestic systems are not well constructed to utilize the technological capability. Knowledge can be learned through books and education programs rather than FDI, but sometimes supplement knowledge, environments and systems must be coordinated all together to fully utilize the knowledge for innovation. If a country in middle income cannot offer favorable environments and systems or domestic supply chain is not sophisticated enough, then the country inevitably relies on foreign efforts to incubate indigenous technological capability for innovation. From this situation, we derive hypotheses as follows:

H1: Efforts by foreign firms from developed countries to incubate national innovative capacity are a key to economic growth for lower-middle income countries to escape or avoid falling into the lower-middle income trap.

At a later stage of economic development, a country becomes more independent of knowledge reliance on foreign advanced countries. Even if full independence is not achievable (nor desirable) because resources and competences are dispersed organizationally and geographically, independency accelerates as supplement knowledge accrues, environments and systems to incubate knowledge for innovation are arranged, and domestic supply chains are formed. As a result, firms in middle income countries begin to compete with those in high income countries with their own efforts. Our second hypothesis is as follows:

H2: Efforts by domestic firms to incubate national innovative capacity are a key to economic growth for upper-middle income countries to escape or avoid falling into the upper-middle income trap.

The first hypothesis is how not to be trapped in the lower-middle income level and enter to the upper-middle income level. The second hypothesis is how not to be trapped in the upper-middle income level and enter to high income level.

4. Data - Technological potentials

Before addressing our main questions, we explain our data. We extensively use patent data for our analysis. The patent database for this research is taken from the EPO's PATSTAT (ver. April 2010). Among various patent office data available in PATSTAT, we limit the patents granted by the US Patent and Trademark Office (US PTO). Patenting is a costly activity and is subject to a tradeoff between market potential and cost. Because of the US market's global significance, companies file economically and technologically valuable patents in the US, despite the high cost. We further narrow the dataset by the application year. We retrieve patent data applied from 1975 to 2005 because patent data applied before 1975 are incomplete with many missing data.

4.1. The number of inventors in each country

Figures 1 to 16 show the number of inventors in each country in the log scale and the number of inventors per million people. We counted the number of inventors based on their addresses. The number of inventors in each country is calculated by the address of each inventor.[3] In the prior innovation literature, sometimes, 'Researchers in R&D' and 'Technicians in R&D'[4] reported by the World Bank is used. However, those indicators are very incomplete, available for only a limited number of countries. In addition, these are number of people engaged in R&D and not necessary led to any outcomes. We decided to use the number of inventors as the number of the people engaged in R&D.

The first set of figures, Figure 1 to Figure 6, show the case of the countries in high income as of 2010. Figure 1 shows the case of Asian and Latin American countries. All the

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[3] The address is not always the nationality of each inventor.

[4] - 'Researchers in R&D': Researchers in R&D are professionals engaged in the conception or creation of new knowledge, products, processes, methods, or systems and in the management of the projects concerned. Postgraduate PhD students engaged in R&D are included.

- 'Technicians in R&D': Technicians in R&D and equivalent staff are people whose main tasks require technical knowledge and experience in engineering, physical and life sciences (technicians), or social sciences and humanities (equivalent staff). They participate in R&D by performing scientific and technical tasks involving the application of concepts and operational methods, normally under the supervision of researchers.

countries in Figure 1 were classified as middle income countries in 1975, and successfully became high income by 2010, using the criteria of Felipe (2012). Japan has the largest number of inventors, and Hong Kong and Singapore have the least number of inventors. When we scale the number of inventors per million people, the number of inventors in Japan is still the largest (see Figure 2). The slopes of these lines for Korea, Singapore, and Taiwan are steeper than the other countries, implying more rapid growth achieved by Korea, Singapore, and Taiwan compared to other countries. Argentine and Chile have far less inventors than Hong Kong and Singapore even if the population sizes of Argentine and Chile are close to those of Korea and Taiwan, respectively (see Figure 2). That implies that steps that Argentine and Chile took to enter high income might be different from those that Asian countries took.

Figure 3 shows the case of the European countries, which were in the middle income categories in 1975, and successfully became high income by 2010. The numbers of inventors in these countries have been increasing steadily. Finland has more inventors than any other countries with larger population. As expected, Finland has the largest number of inventors even when scaled by the population size (see Figure 4).

Figure 5 shows the case of the US and the European countries, which were already high income in 1975.[5] U.S. has more inventors than any other countries in the first set of figures, and the number of inventors in U.S. continuously increased. Although the number of inventors in the European countries increased as other countries did, the increase is the least. In the U.S., The number of inventors per million people increased rapidly but decreases after the peak in 2000 (see Figure 6). The numbers of inventors per million people in most European countries range between 100 and 300 in the 2000s (see Figure 6). Sweden increased its inventors per million people quite rapidly in the 1990s.

[5] Technically speaking, Austria entered high income in 1976. Nevertheless, Austria is added in Figure 3 for being in high income for 35 years. For brevity, we omitted Canada, Mauritius, Israel, Australia, and New Zealand from the graph. An interesting finding is that Mauritius is a high income country as of 2010, but it has almost no inventors. The explanation for the case of Mauritius is that either there is no patent in Mauritius or there is almost no patent in US filed from Mauritius.

Figure 1: the number of inventors in the countries in high income as of 2010

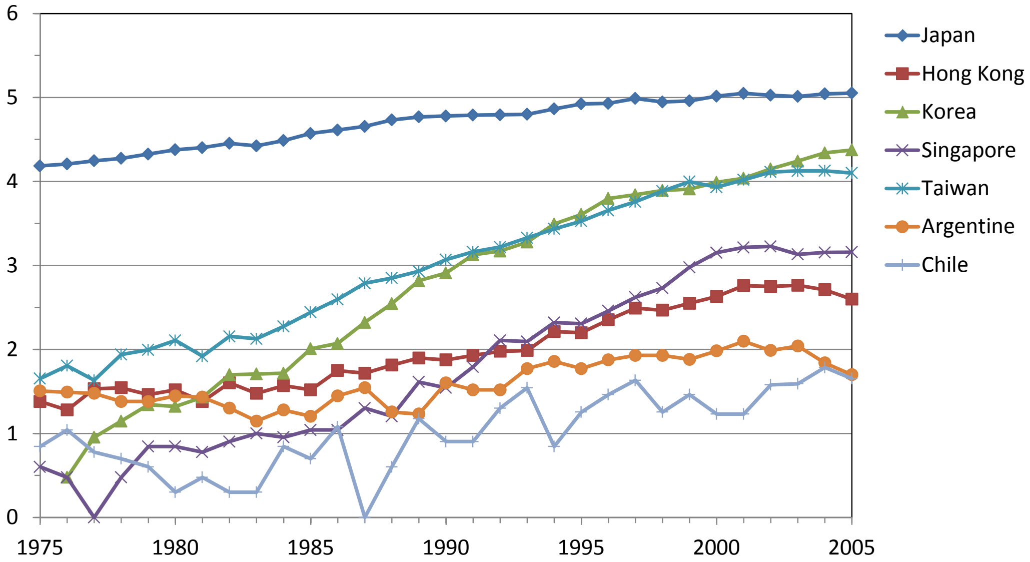


Figure 2: the number of inventors per million people in the countries in high income as of 2010

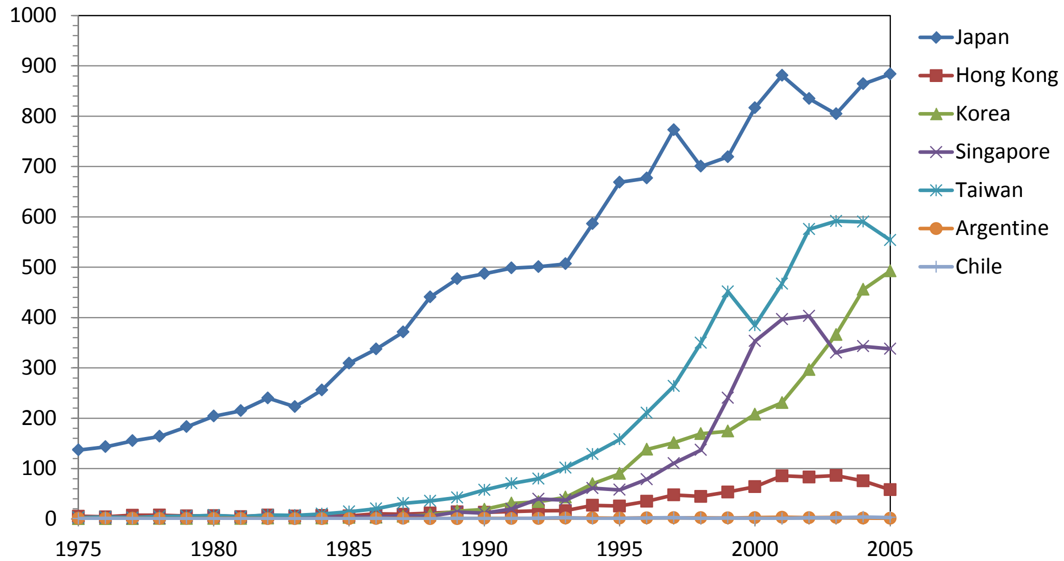


Figure 3: the number of inventors in the countries in high income as of 2010

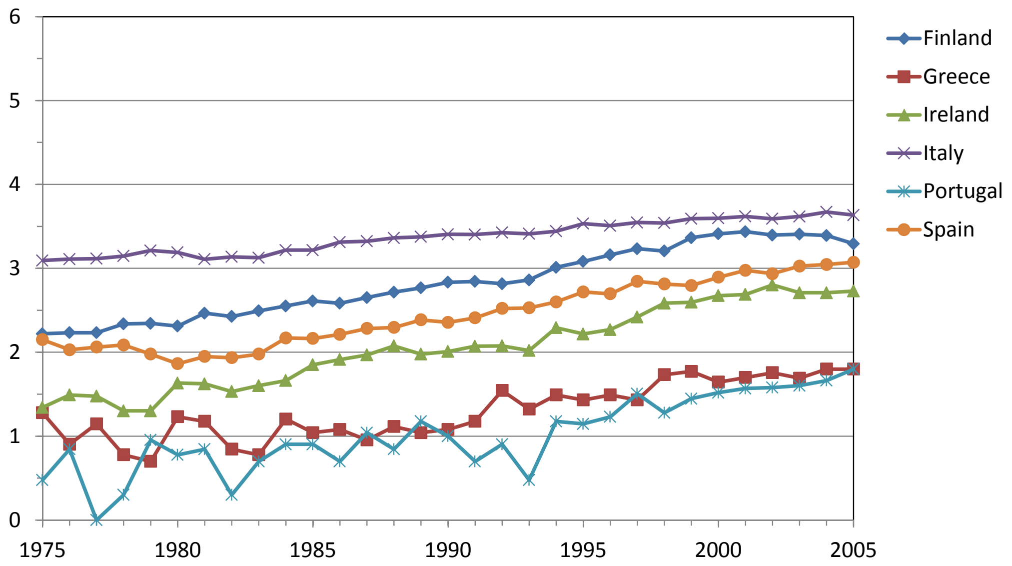


Figure 4: the number of inventors per million people in the countries in high income as of 2010

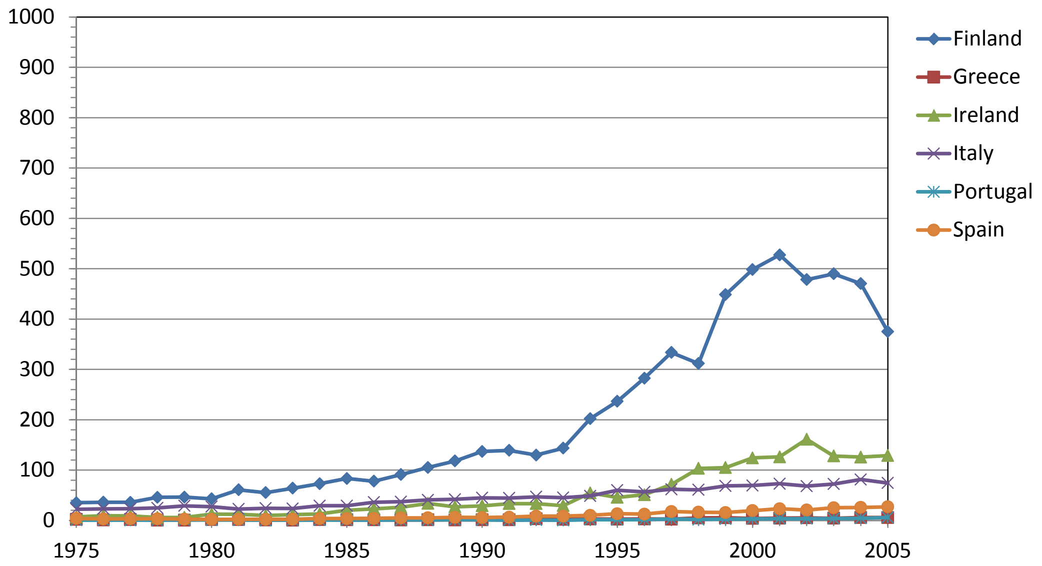


Figure 5: the number of inventors in the countries in high income as of 2010

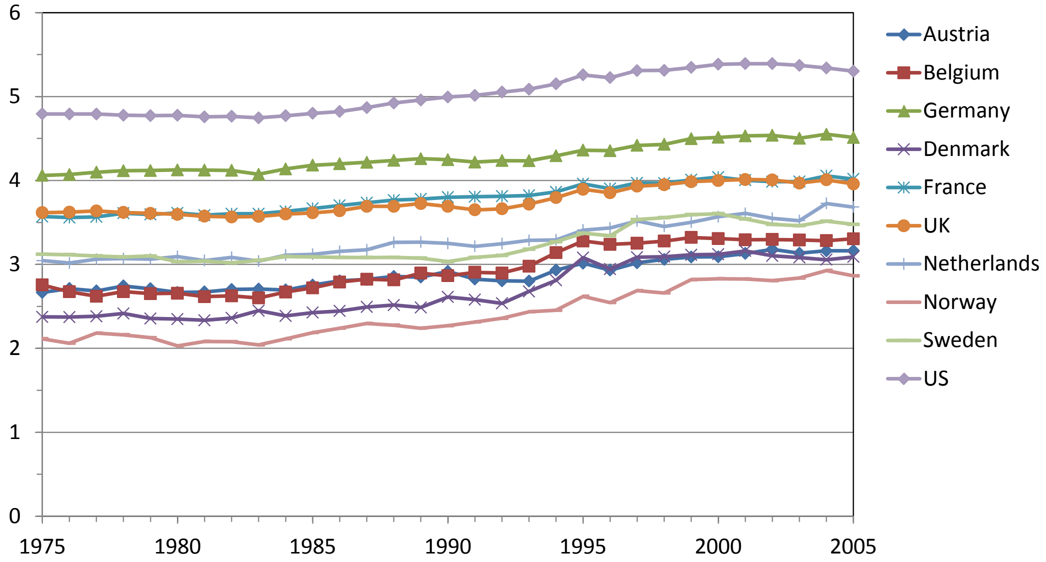
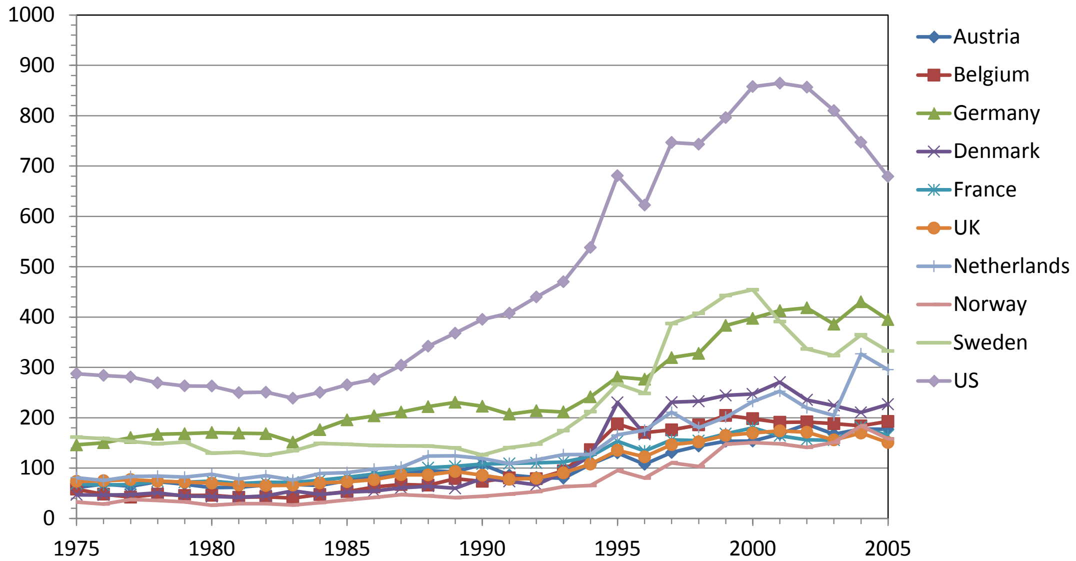


Figure 6: the number of inventors per million people in the countries in high income as of 2010

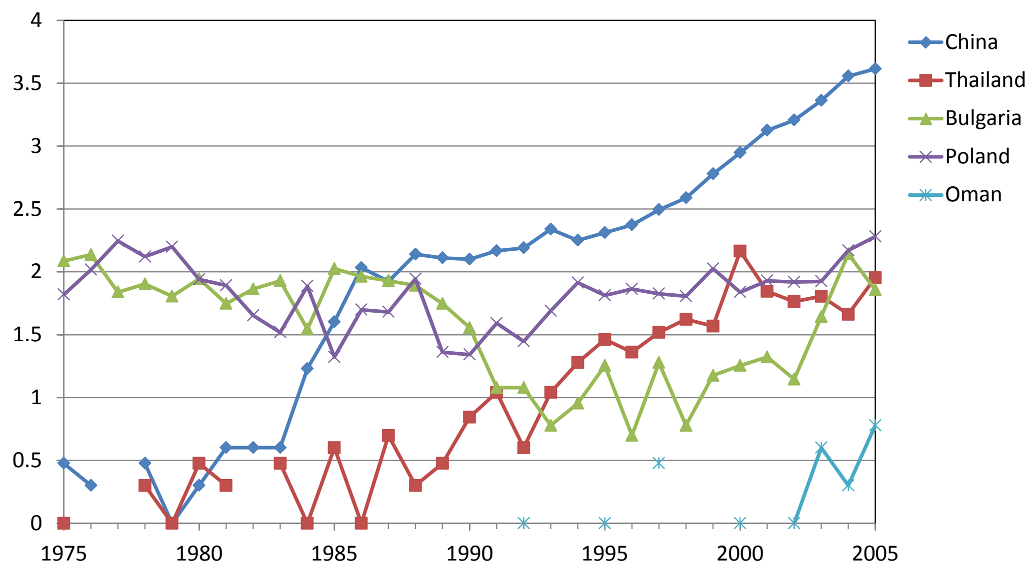


A second set of figures, Figure 7 to Figure 12, show the case of the countries in upper-middle income as of 2010. Figure 7 shows the case of upper-middle income countries which are expected to enter high income. The number of inventors in China increased significantly from the late 1990s. Although the current number of inventors per million people in China appears low because of a large population size (see Figure 8), China has a great potential to increase the number of inventors in future. The number of inventors in Thailand also increased significantly. The number of inventors in Bulgaria decreased greatly in the 1990s, but it increased again in the early 2000s, and that in Poland had been relatively constant between 1975 and 2000s. Compared to other countries in this category, there are almost no inventors in Oman.[6]

Figure 9 shows the case of upper-middle income countries which are expected to be trapped in the upper-middle income trap. The number of inventors in Hungary decreased from 1980s. The decrease is apparent when counting the number of inventors per million people (see Figure 10). The number of inventors in Turkey and Costa Rica increased. However, they are far less than 100. The number of inventors in Mexico had been rather constant between 1975 and the early 1990s, and they increased from the middle of the 1990s.

Figure 11 shows the case of countries trapped in the upper-middle income trap. The number of inventors in Malaysia increased more than any other countries in this category. The increase in Malaysia is clearly observed from the late 1990s when scaled by the population (see Figure 12). The other countries have less than 100 inventors although the number of inventors in Venezuela and Saudi Arabia increased.

Figure 7: the number of inventors in the countries in upper-middle income as of 2010



[6] As was the case for Mauritius, the explanation for the case of Oman is that either there is no patent in Oman or there is almost no patent in US filed from Oman.

Figure 8: the number of inventors per million people in the countries in upper-middle income as of 2010

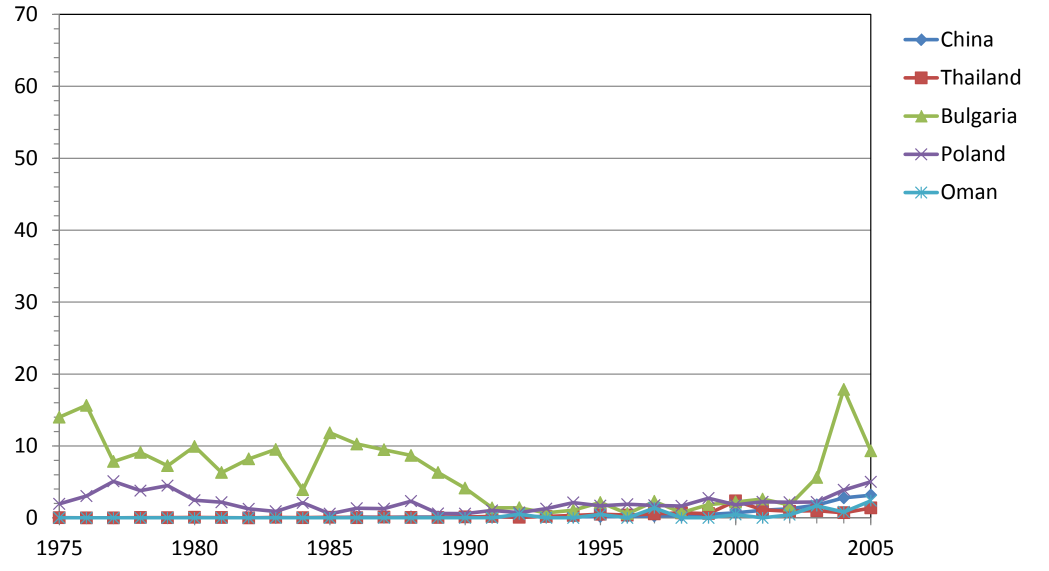


Figure 9: the number of inventors in the countries in upper-middle income as of 2010

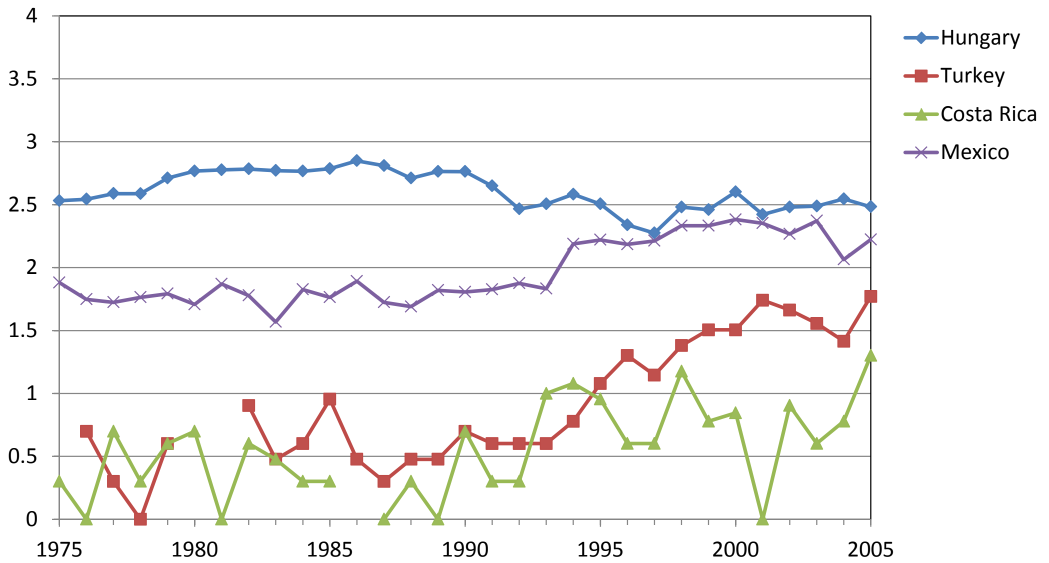


Figure 10: the number of inventors per million people in the countries in upper-middle income as of 2010

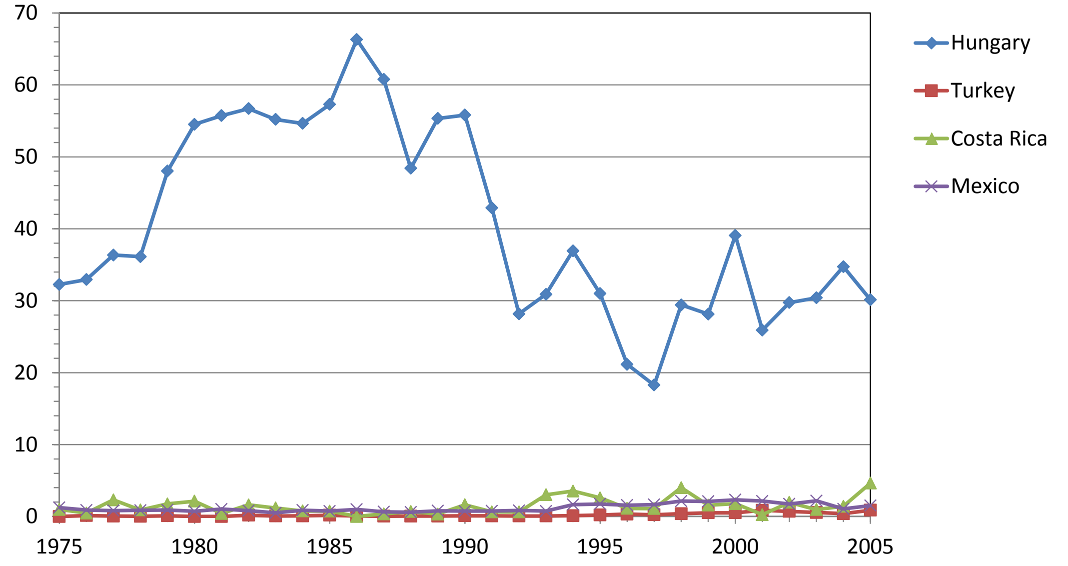


Figure 11: the number of inventors in the countries in upper-middle income as of 2010

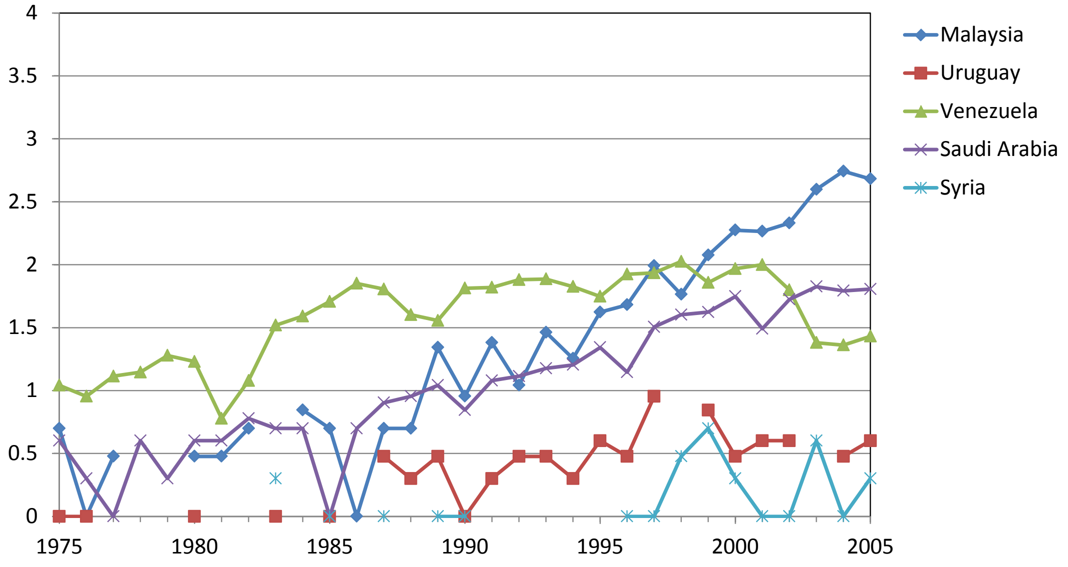
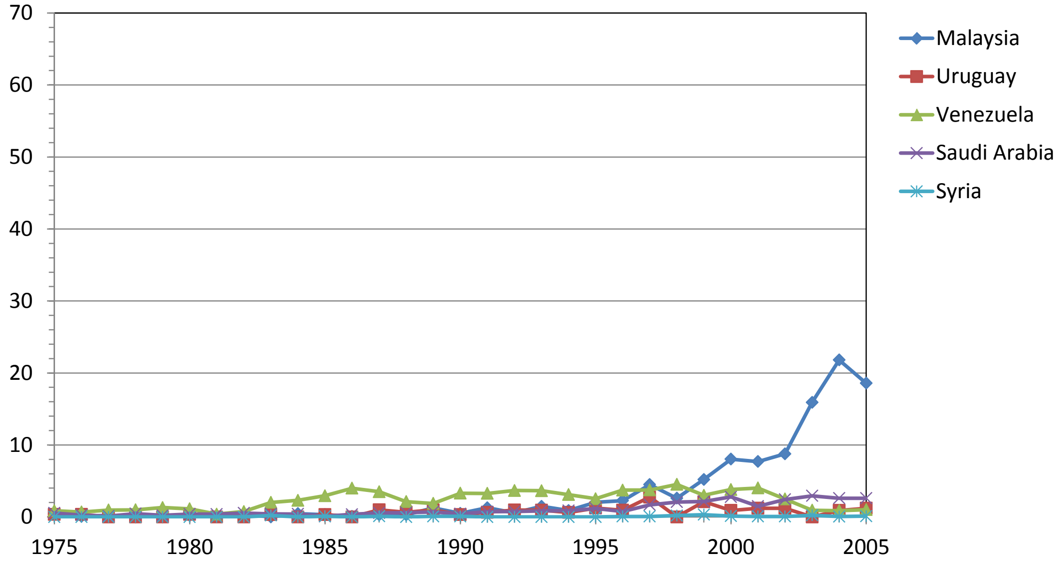


Figure 12: the number of inventors per million people in the countries in upper-middle income as of 2010



A third set of figures, Figure 13 to Figure 16, show the case of the countries in lower-middle income as of 2010. Figure 13 shows the case of lower-middle income countries which are expected to enter upper-middle income and which are expected to be trapped in lower-middle income. The former countries are India, Cambodia, Myanmar, Vietnam, and Mozambique, and the latter countries are Indonesia, Pakistan, and Honduras. The number of inventors in India significantly increased (see Figure 14). However, the number of inventors, even taking into account of the population size, remains relatively small compared to countries in higher income categories. All the other countries except Indonesia had less than 10 inventors every year.

Figure 15 shows the case of the selected lower-middle income trapped countries,[7] namely Brazil, Philippines, Romania, and South Africa. These countries saw the number of inventors to increase during these period, although the increase in the number of inventors does not seem to keep up with the increase in population (see Figure 16).

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[7] Other countries in this category includes Albania, Algeria, Bolivia, Botswana, Congo, Colombia, Dominican Republic, Ecuador, Egypt, El Salvador, Gabon, Guatemala, Iran, Jamaica, Jordan, Lebanon, Libya, Morocco, Namibia, Panama, Paraguay, Peru, Sri Lanka, Swaziland, Tunisia, and Yemen. These countries have very few number of inventors.

Figure 13: the number of inventors in the countries in lower-middle income as of 2010

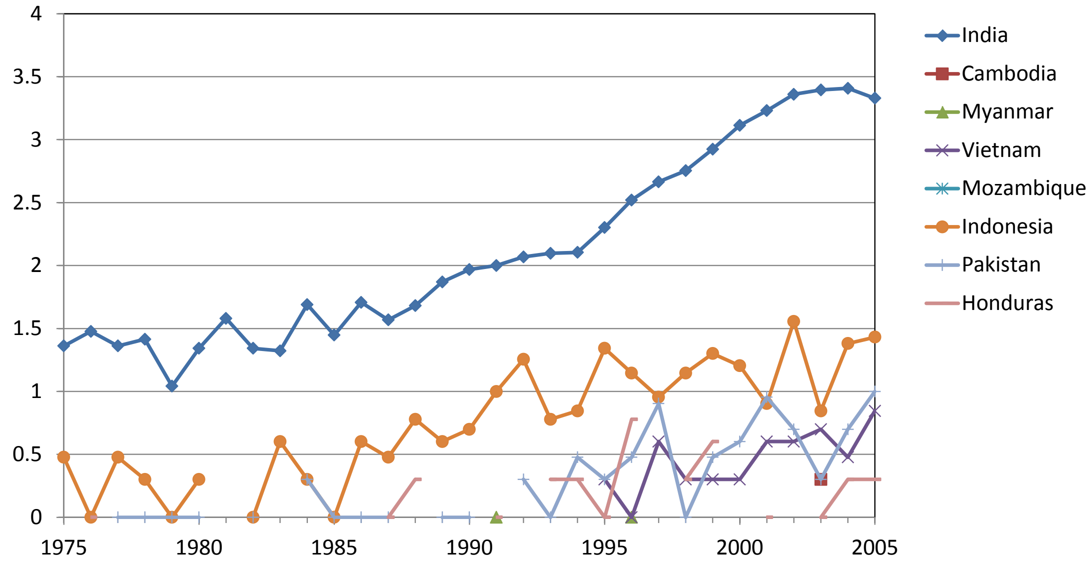


Figure 14: the number of inventors per million people in the countries in lower-middle income as of 2010

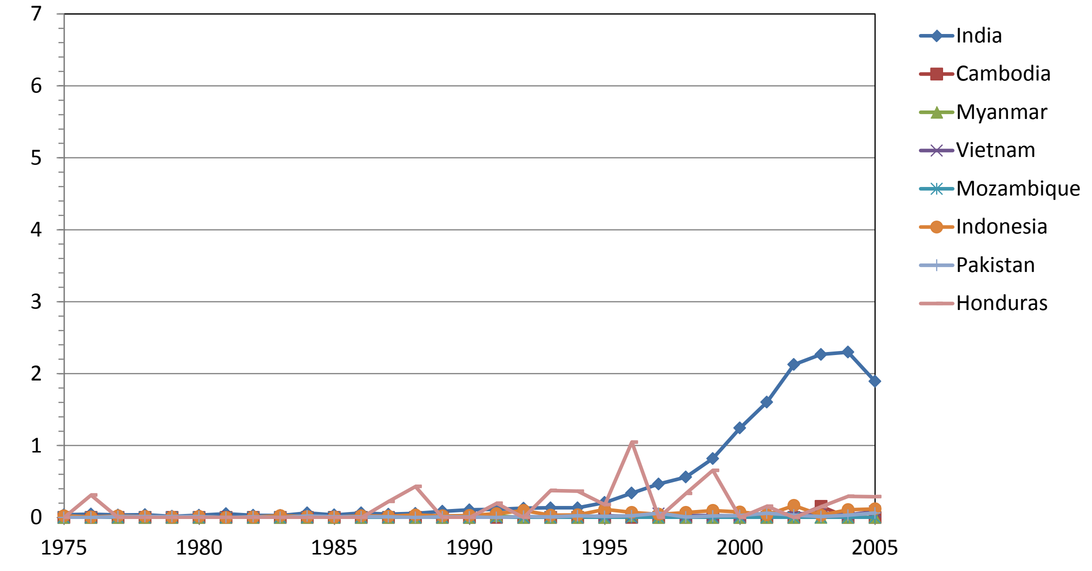


Figure 15: the number of inventors in the selected countries in lower-middle income as of 2010

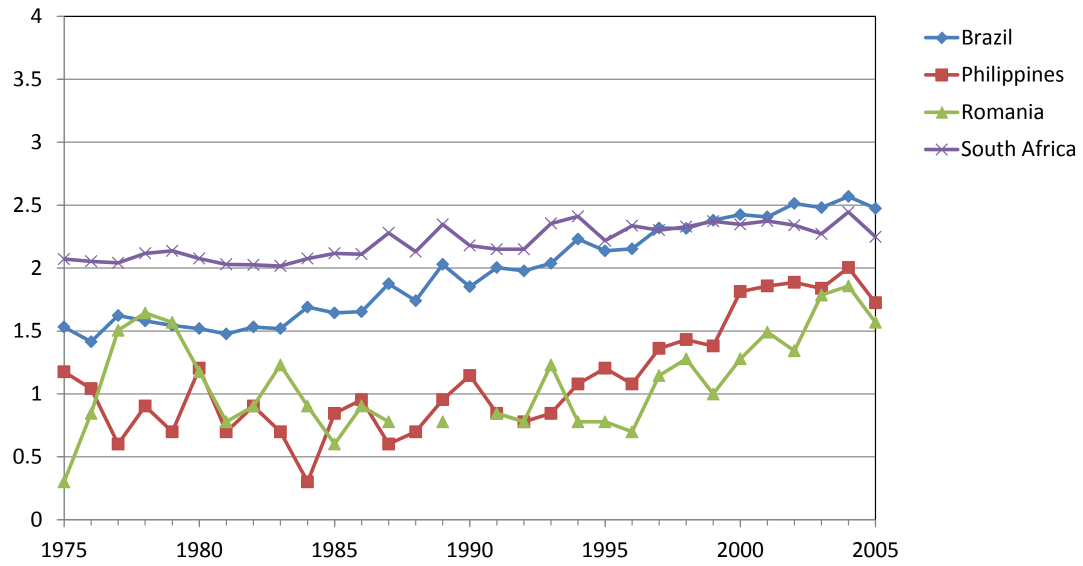
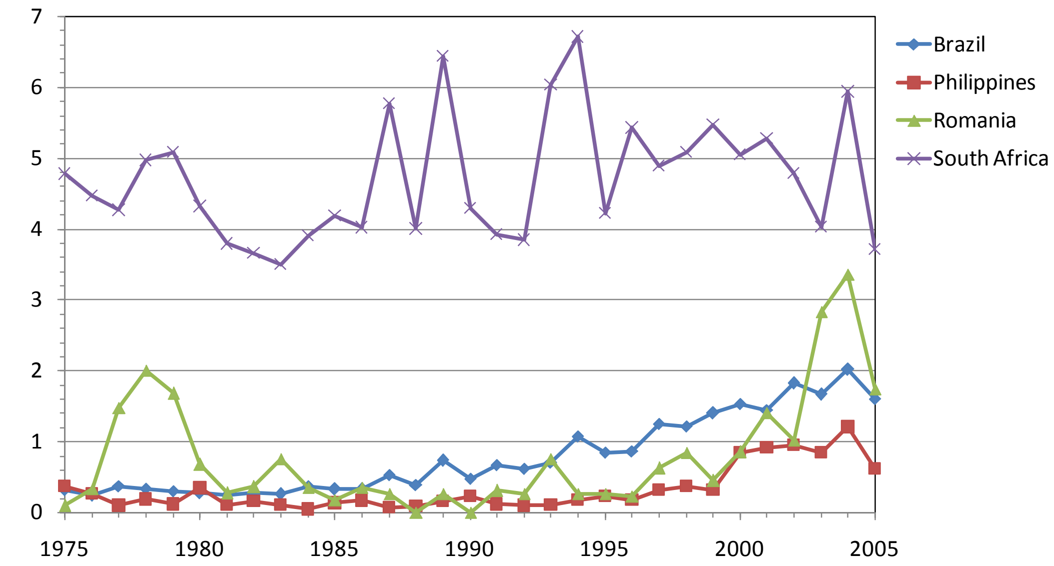


Figure 16: the number of inventors per million people in the countries in lower-middle income as of 2010



The number of patents and the number of inventors for low income countries are rather sparse. All we can say is that they have a small number of inventors, typically having less than 2 inventors per million people. Some countries, mainly sub-Saharan African countries had zero inventors during this period.[8]

Throughout the figures in this subsection, it is apparent that higher income countries tend to have a larger number of inventors and these countries saw a faster growth in the number of inventors than the population increase. One characteristic of middle income trapped countries is that these countries have too few inventors compared to their population sizes. Their inventors decreased or stayed constant despite the growth in their population size. There are a few exceptions such as Malaysia. The number of inventors in Malaysia increased significantly, but the country is still upper-middle income trapped. Greece and Portugal became high income countries with fewer inventors than some of middle income countries.[9]

4.2. Rate of innovative incubation within a country

We measure to what extent domestic and foreign firms contribute to incubating inventors in a country. This allows us to investigate how much a country is capable to incubate innovation within the country. We calculate the rate in the following way. First, each patent per national origin is counted in proportion of national origins of inventors from their addresses. Second, each proportional patent count is summed for each national origin. Third, we consider if the national origin of an applicant from his address is the same as that of an inventor. As was in Section 4.1, those addresses are not always the nationality. Finally, the innovative incubation rate is calculated as the following equation:

$$\text{Innovative Incubation Rate}(\%) = \frac{(X)}{(X)+(Y)} \times 100 \qquad \text{Eq. (1),}$$

where 'X' refers to the number of patents applied by firms located in the same country and 'Y' refers to the number of patents applied by firms located in any other country. If an inventor contributed to an applicant from the same national origin, we regard the case as indigenous contribution. Otherwise, we regard the case as foreign contribution. For example, we consider a case where a patent is invented by three inventors in three different countries, say countries A, B, and C, and is applied by two applicants from two countries A and B. Then, A incubated 1/3 indigenous innovation, B did 1/3 indigenous innovation, and C did 1/3 foreign innovation. The results are shown in Figures 17 to 23.

The first set of figures, Figure 17 to Figure 19, show the case of the countries in high income as of 2010. Figure 17 shows the case of Asian and Latin American countries that

[8] These are Afghanistan, Bangladesh, Angola, Benin, Burundi, Central African Republic, Democratic Republic of Congo, Eritrea, Guinea Bissau, Lesotho, and Togo.
[9] Although Greece is facing a significant debt problem since 2012.

moved successfully from middle income to high income. Cases of Japan, Korea, and Taiwan show that their innovative incubation rate is constantly more than 95 per cent. That is, inventions by inventors in those countries are mostly applied by domestic applicants. On the other hand, cases of Argentine, Hong Kong, Chile, and (recent) Singapore show that their innovative incubation rate by domestic applicants has been decreasing even if the number of inventors increased in those countries (see Figure 17). This implies that inventors in those contribute to innovation of foreign companies that have offices in those countries. That finding can be a model for countries with insufficient innovative actors.

Figure 18 shows the case of European countries which were in middle income in 1975, and became high income by 2010. The case of Finland shows that its innovative incubation rate keeps high rate, constantly more than 90 per cent. A common trend is that the innovation incubation rate decreases more or less for all the countries. This implies that domestic R&D staff contribute more to foreign firms than to domestic firms. It is not clear if that was caused by a decrease in domestic firms or by an increase in foreign firms. Nevertheless, that confirms that internationalization of R&D is accelerating.

Figure 19 shows the case of the US and European countries, which had been in high income since 1975. As were the cases in Figure 18, a common trend is that the innovation incubation rate decreases for all the countries. That is, internationalization of R&D is accelerating in these countries. The case of U.S shows that almost all inventors in U.S. contribute to domestic companies. Even if the curve dropped in the mid-2000s, U.S. still keeps a high rate. One interesting case is the Netherlands'. The Netherlands had kept its level between 40 per cent and 50 per cent until the middle of the 1990s. However, the country increased its level, which implies that R&D staff in the Netherlands contributes more to domestic firms than to foreign firms in the Netherlands. The curve seems to be more or less correlated to the situation that the Netherlands experienced between 1982 and 2000 (den Butter and Mosch 2003).

Figure 17: innovative incubation rate per country in high income as of 2010

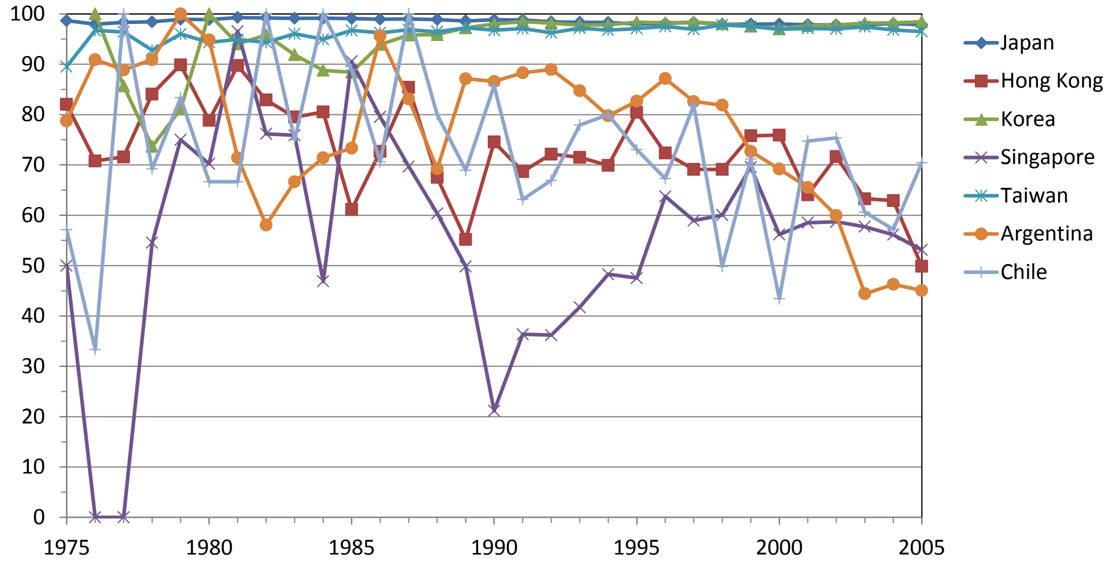


Figure 18: innovative incubation rate per country in high income as of 2010

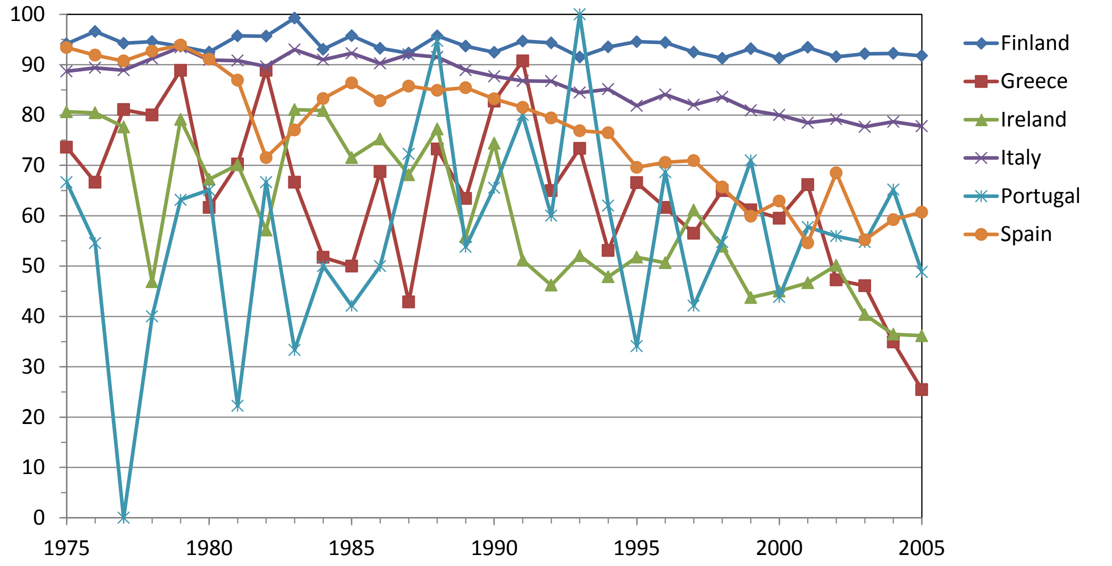
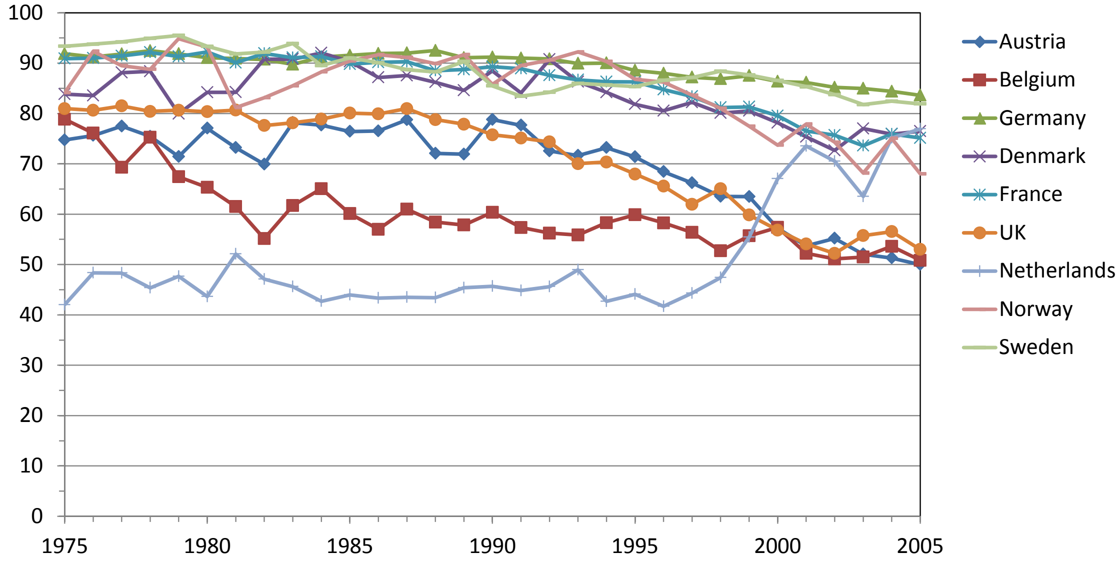


Figure 19: innovative incubation rate per country in high income as of 2010



The second set of figures, Figure 20 to Figure 23, show the case of the countries in upper-middle income as of 2010. Lines in the second set of figures set do not show a consistent picture among countries compared to those seen in the first set of figures. Figure 20 shows the case of upper-middle income countries which are expected to enter high income. The innovation incubation rates of Bulgaria, China, and Poland decrease. Especially, China saw incubation rate to decrease in the late 1980s after peaking in 1986. That might be a result of FDI inflows rapidly increased in the 1980s in China. One difference of China from Bulgaria and Poland is that China's line increases from the early 2000s. Considering the fact that the number of inventors in China increased rapidly from the 1990s as seen in Figure 7, China's increase in its innovative incubation rate implies that the more inventors work for Chinese firms.

Figure 21 shows the case of upper-middle income countries which are expected to be trapped in upper-middle income. Hungary and Mexico saw a dramatic decrease in the incubation rate from the late 1990s, which implies that the more inventors in those countries work for foreign companies located in Hungary and Mexico.

Figure 22 shows the case of upper-middle income trapped countries. First, Malaysia's innovative incubation rate has decreased for a long time. On the other hand, Venezuela and Saudi Arabia have been high in the innovative incubation rate compared to any other countries in the second set of figures. The reason for the cases of Venezuela and Saudi Arabia is not clear.

Figure 20: innovative incubation rate per country in upper-middle income as of 2010

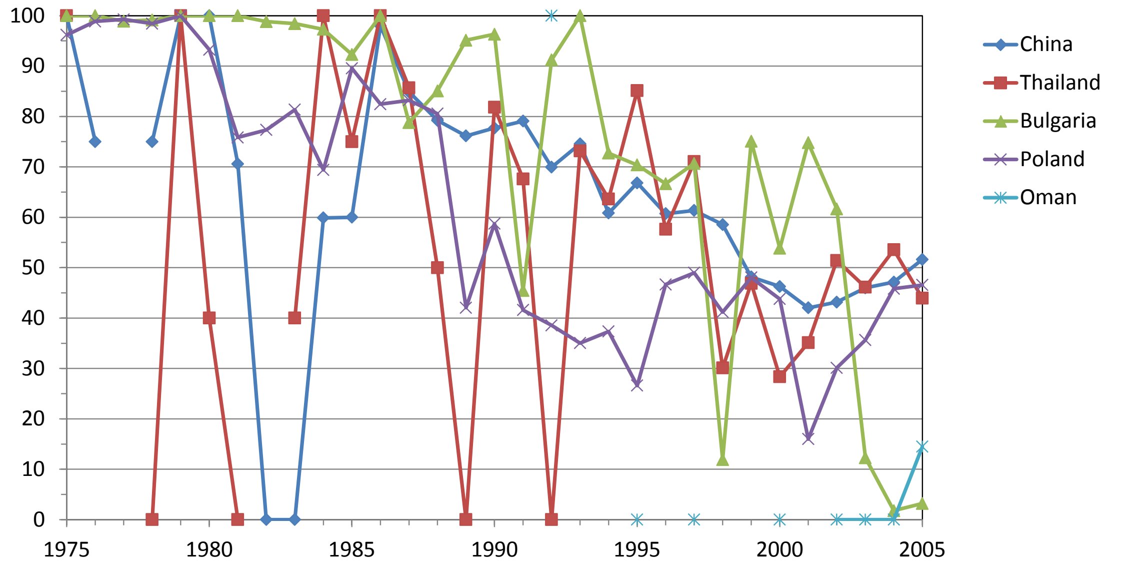


Figure 21: innovative incubation rate per country in upper-middle income as of 2010

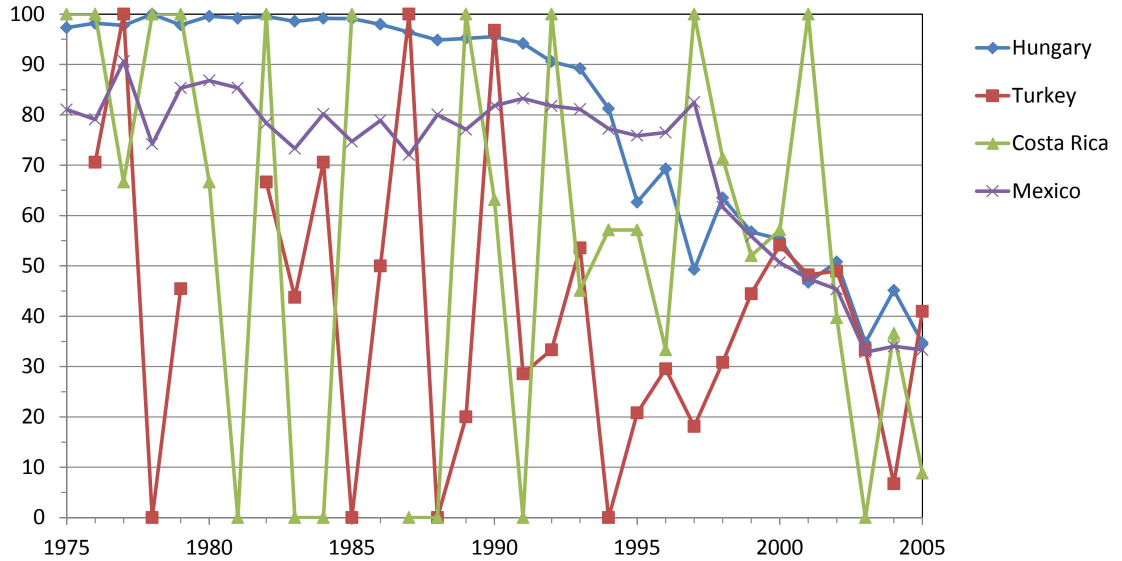
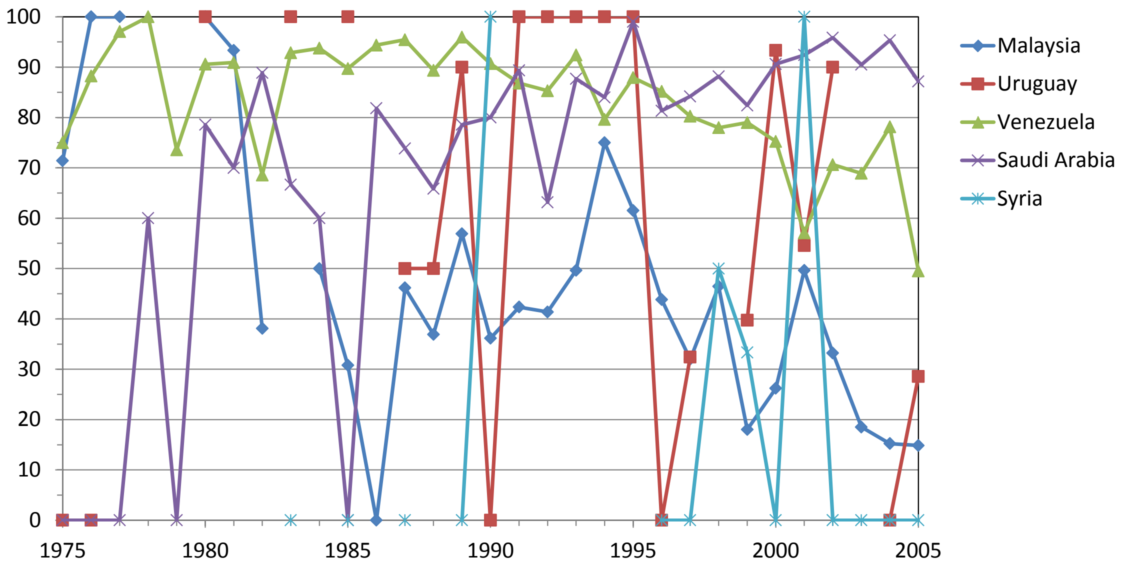


Figure 22: innovative incubation rate per country in upper-middle income as of 2010

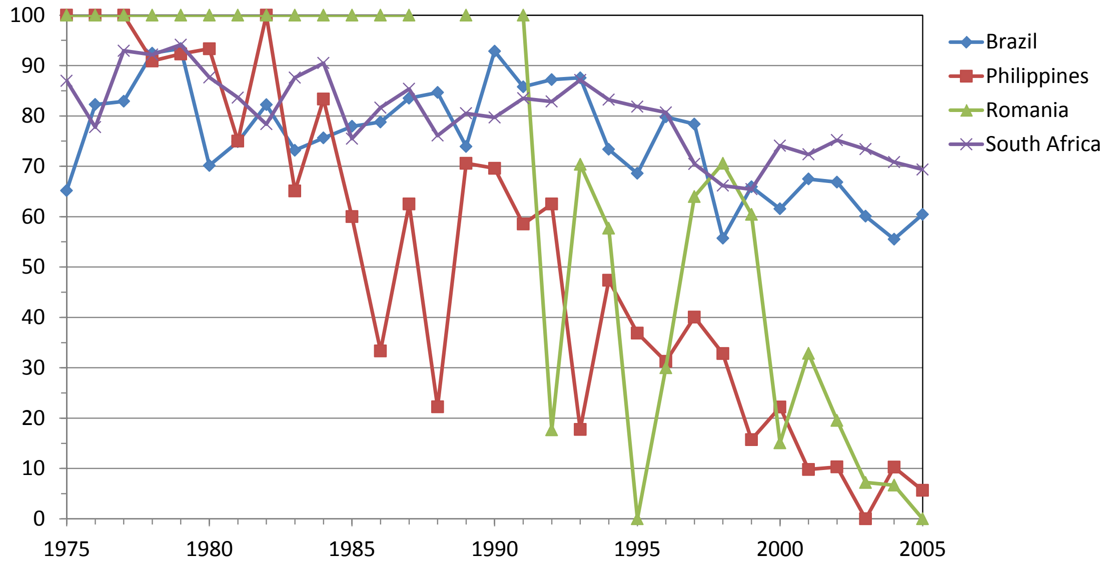


Finally, Figure 23 shows the case of the selected countries in lower-middle income as of 2010. Although there are 37 countries in this category, only India, Brazil, Philippines, and South Africa are worth a discussion.[10] The innovation incubation rates of Brazil, India, Philippines, and South Africa decrease as time goes on, reflecting greater influences of the foreign firms.

Throughout the figures in this subsection, it is shown that many countries in high income and upper-middle income decreased their domestic innovative incubation rates in general. This finding implies that internationalization of R&D and innovation activities has been accelerating. There is a difference in this finding between countries in high income and those in upper-middle income; while countries in high income category still maintain relatively high domestic innovative incubation rates, those in upper-middle income, especially those soon-to-be and already trapped in upper-middle income, showed significant drop in their domestic innovative incubation rates. That implies that to enter upper income level, a country may need to utilize its domestic human resources for its own innovation rather than letting them be utilized for foreign firms.

[10] There is a great deal of heterogeneity among these countries and issues associated with a small number of inventors.

Figure 23: innovative incubation rate per country in lower-middle income as of 2010



5. Empirical Results and discussion

To quantitatively test our hypotheses, we use patent data and national statistics. We postulate that the transition from one category of income groups to other depends on the level of innovation capabilities accumulated in a country controlling for other factors. In addition, since the definition of the trap by Felipe (2012) is defined as duration in which a country spend in a particular income category, we utilize a duration model to test out hypothesis. Specifically, we employ the following model,

$$h(t, x) = f(\beta x)$$

where h(t,x) is a hazard rate (i.e. time to transition to the next category of income), β is the parameter to be estimated, and x includes explanatory and control variables. For the explanatory variables, we use the "innovation capability". In the literature, often this is measured by the number of patents. What we are interested in this study is to see if the number of patents is important or the inventors (i.e. the human capital). If the latter is more important, then whether the inventors are used for domestic or foreign patents make any difference. The data for patents and inventors are from the PATSTAT database. For the control, we include the capital stock from the latest Penn World Trade table (Feenstra, Inklaar and Timmer 2013). We also include the data on human capital measured by the average years of schooling to control for the general availability of human capital in an economy (Barro and Lee 2013). For the data on the transition of countries from one category to the higher up one, we use the data provided in Felipe (2012). In this data, we have a total of 77 countries. See Table 1 for the details on the transitions.

Table 1: # of countries in each income categories

Type of transition	# of countries	Average years to transition to the next categories (From 1975 to 2005)
Low income (no transition)	47	-
Of which, from low to lower-middle income	19	15.2
Lower-middle income countries	57	-
Of which, from lower to upper-middle income	19	18.6
Upper-middle income countries	30	-
Of which, from upper-middle to high income	16	11.6

Note: For each category of income, some countries may appear multiple times if they have changed their income categories between 1975 and 2005.

A priori, we do not expect that time spent in one income categories should have any impact on the total duration of a country to be in an income category. That is, having spent 10 years in lower-middle income country status should not have any bearing on how long a country will spend in these income categories. All what matters are country characteristics. For this reason, we use Cox proportional hazard model.

Based on our hypotheses, we run three different regressions corresponding to each income level transition (from low to lower-middle, lower-middle to upper-middle, and from upper-middle to high). Although our primary interest is in income level transitions from lower-middle to upper-middle and from upper-middle to high, we conduct the income level transition from low to lower-middle for comparison. What we are interested in is the coefficient estimates on “innovation capability”. For the transition from low to lower-middle, we do not think this will have any significant impact. At this stage of the economic development, general accumulation of capital and human capital might be the most important driver. Once a country reaches a middle income status, we believe that "innovation capability" may be more important. Therefore, we expect the coefficient estimates on innovation capability to be positive. Further, we expect that innovation capabilities nurtured by domestic firms will be more important in the transition from upper-middle to high income, so we expect this to be positive.

For this reason, we run 6 different models for each transition case. The model 1 examines the relationship between the transition and typical growth variable: capital and human capital. Model 2 examines the issue with innovation measured by the total number of patents associated with the country. This is a typically way in which innovation capability is measured in the previous studies. Models 3 and 4 examine the issue with innovation capability measured by with the total number of inventors and the total number of inventors per million population, respectively. Model 5 and 6 divide the total number of inventors into two: domestic residence and foreign residence. Since the correlations between the independent variables of interest are high, we add one independent variable in each regression model separately. In addition, we added major patenting country dummies in each model to avoid bias by heavy patent applicants in each income level.

As one key assumption of the Cox proportional hazard model is that the hazard rate does not depend on current length of time that a country has remained in the same income category, we tested if our data violate the assumption. We included interaction terms between the independent variables and the length of time. The result showed that the interaction terms were insignificant which supports that our data is suit for the cox proportional hazard model.[11]

The first set of regressions looks at the case of the transition from the low income to the lower-middle income (Table 2). There are three findings. Fist, capital is significant and positive in all specification. This is consistent with growth theory and previous findings from the literature. Second, the total number of inventors per

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[11] Results for these are omitted for brevity. They are available upon request

million population shows statistical significance at the 5 per cent level while that of the absolute number of inventors doesn’t. This finding implies that human resource which is the main actor of innovation is necessary even at the very early stage of economic growth. And, the key is not absolute quantity but proportion. Third, the total number of domestic inventors per million population shows statistical significance at the 1 per cent level while that of foreign inventors per million does not. This finding implies that domestic innovative actors contribute to the economic growth of the country even at the very early stage.

The second set of regressions is for the case of the transition from the lower-middle income to the upper-middle income (Table 3). None of independent variables except capital shows statistical significance in any model. This implies that at this level of the development, capital accumulation and deepening is the most important driver of the growth, which is consistent with the neoclassical growth theory.

Table 2. Regression (1)

DV: occurrence of a low income country's entering the lower-middle income.

	1	2	3	4	5	6
Patent		0.1040				
		[0.92]				
Inventors			0.2229			
			[1.47]			
Inventors per M population				2.0741		
				[2.40]**		
Domestic inventors					0.2068	
					[1.24]	
Foreign inventors					0.2741	
					[1.09]	
Domestic inventors per M population						10.6869
						[3.08]***
Foreign inventors per M population						0.7854
						[0.28]
Human capital	1.5369	1.2919	1.2823	1.6841	1.3414	1.1988
	[1.84]*	[1.56]	[1.55]	[2.01]**	[1.56]	[1.29]
Log(capital stock)	0.7436	0.6617	0.4915	0.7777	0.5029	0.7538
	[3.16]***	[2.79]***	[1.84]*	[3.23]***	[1.85]*	[3.17]***
China	-2.0218	-5.2736	-43.142	-2.2616	-41.0811	-2.7491
	[-1.47]	[-1.02]	[-0.02]	[-1.60]	[-0.03]	[-1.74]*
India	-1.4387	-38.1414	-306.8099	-3.0347	-287.7037	-12.8193
	[-1.12]	[-0.91]	[-1.47]	[-1.79]*	[-1.28]	[-2.87]***
N	798	798	798	798	798	798

* p<0.1, ** p<0.05, *** p<0.01

Table 3. Regression (2)

DV: occurrence of a lower-middle income country's entering the upper-middle income.

	1	2	3	4	5	6
Patent		0.0098				
		[1.49]				
Inventors			0.0008			
			[0.35]			
Inventors per M population				0.0046		
				[0.17]		
Domestic inventors					0.0008	
					[0.33]	
Foreign inventors					0.0019	
					[0.03]	
Domestic inventors per M population						0.0013
						[0.04]
Foreign inventors per M population						0.2316
						[0.78]
Human capital	1.095	0.9571	1	1.0441	0.9988	0.9846
	[1.42]	[1.24]	[1.22]	[1.25]	[1.22]	[1.16]
Log(capital stock)	0.4412	0.3268	0.4176	0.439	0.4167	0.4652
	[2.23]**	[1.58]	[2.01]**	[2.21]**	[1.96]**	[2.28]**
China	-41.3298	-42.9213	-42.8266	-44.2985	-44.3852	-44.3831
	[-0.00]	[-0.00]	[-0.00]	[.]	[-0.00]	[.]
India	-40.8371	-42.199	-42.5562	-42.8128	-43.4567	-42.884
	[-0.00]	[-0.00]	[-0.00]	[.]	[.]	[.]
Korea	1.2572	0.8851	1.2785	1.2914	1.2787	1.3257
	[1.05]	[0.67]	[1.06]	[1.06]	[1.06]	[1.08]
Taiwan	1.9888	0.6252	1.9262	1.9826	1.9274	2.0426
	[1.70]*	[0.37]	[1.63]	[1.69]*	[1.63]	[1.74]*
N	1098	1098	1098	1098	1098	1098

* p<0.1, ** p<0.05, *** p<0.01

The third set of regressions is looking at the case of the transition from the upper-middle income to the high income (Table 4). There are four findings. First, the coefficient estimates for the number of patents are statistical significance at the 1 per cent level. Second, both of the total number of inventors and that of inventors per million population show statistical significance at the 1 per cent level. This finding implies that human resource which is the main actor of innovation and actively involved in innovation activities is necessary to become a high income country. And, both absolute quantity and proportion are the keys. Third, the total number of domestic inventors and that of domestic inventors per million population show statistical significance while those of foreign inventors don't. This finding implies that domestic innovative actors contribute to the economic growth of the country at this stage. Fourth, capital is no longer important in the growth process and the transition from the upper middle income to high oncome countries. This is exactly the concerns that the middle income countries and have, and also the definition of the middle income country. The growth is not driven by "perspiration" but "inspiration" to borrow the words from Krugman (Krugman 1994).

Table 4. Regression (3)

DV: occurrence of a lower-middle income country's entering the upper-middle income.

	1	2	3	4	5	6
Patent		0.0088				
		[3.27]***				
Inventors			0.0048			
			[3.42]***			
Inventors per M population				0.0422		
				[2.70]***		
Domestic inventors					0.0084	
					[2.23]**	
Foreign inventors					-0.0645	
					[-1.04]	
Domestic inventors per M population						0.0339
						[1.90]*
Foreign inventors per M population						0.2847
						[1.13]
Human capital	0.875	0.3464	0.2119	-0.6415	0.5801	-0.9448
	[1.04]	[0.38]	[0.24]	[-0.60]	[0.61]	[-0.84]
Log(capital stock)	-0.1243	-0.6086	-0.5808	-0.0208	-0.771	0.2469
	[-0.43]	[-1.88]*	[-1.81]*	[-0.06]	[-2.03]**	[0.56]
Japan	3.478	-52.8349	-67.2088	-1.6411	-114.137	-1.2057
	[2.01]**	[-3.17]***	[-3.33]***	[-0.66]	[-2.26]**	[-0.48]
Korea	1.2318	-14.6444	-15.3871	-0.4014	-19.5918	-0.5951
	[0.92]	[-2.71]***	[-2.87]***	[-0.24]	[-2.63]***	[-0.36]
Taiwan	1.3163	-10.1076	-6.1951	-0.9416	-10.3434	-0.6252
	[1.13]	[-2.48]**	[-2.18]**	[-0.63]	[-2.02]**	[-0.41]
N	275	275	275	275	275	275

* p<0.1, ** p<0.05, *** p<0.01

Our primary interest is in finding the determinants to avoid or escape the middle income traps. Based on the result of Regression (2) in Table 3, our first hypothesis is not supported. On the other hand, based on the result of Regression (3) in Table 4, our second hypothesis is supported. We believe that our measure of inventers capture the innovation capabilities better than, say, a number of researchers that engage in R&D

because these are the actual people who have contributed to innovation outcome. Also the importance of domestic inventers means the importance of firms located in the same country to do innovation. Remember that all inventers are domestic. The difference between “domestic inventor” and “foreign inventor” is whether the patent that they work for is assigned to an entity residing domestically or foreign. Our data cannot easily differentiate the nationality of the firms nor inventors. What is important is the existence of firms that can organize innovation activities and firms that utilize locally residing inventers. These firms can be domestic or foreign subsidiaries. The important point is that they are located locally.

6. Conclusion

This study focused on a country’s innovation potential and analyzed how one’s innovation potential contributed to avoid, or escape if already trapped, the middle income trap. We measured the extent of innovative potential by counting the number of inventors contributing patents assigned domestically and abroad from patent data. We observed positive correlation between the income level and the innovation potential measured by the number of inventors. The amount of inventors in lower- and upper-middle income trapped countries either stayed constant or decreased despite the population size growth. We tested how such innovation potential helps avoid or escape middle income traps. We formulated two hypotheses, one on the lower-middle income trap and the other on the upper-middle income trap. Regression results suggested that innovation potential may not be a determinant for a lower-middle income country to enter the upper-middle income level. At this stage of development, capital accumulation is more important. On the other hand, innovation potential, especially for domestic one, helped upper-middle income countries avoid the upper-middle income trap and enter the high income level. One interesting finding was that the same was applicable for a low income country to become a middle income country.

This study provides a policy implication for developing countries in terms of innovation potential. Our result said that the inventors inside a country play a role as one of innovation potential of the country and they are a determinant to achieve economic growth via innovation. And, their work is effective not only in upper-middle income countries but also low income countries. One practical method to achieve such a goal is investment to educational system including schools, job training, and so on to further enhance the capability of each person even at the early stage of development since development in human capital takes long time. If a country has been investing educations and is middle income trapped, education system should be updated or redesigned. Another practical method is to accept highly skilled personnel. Hiring highly skilled personnel is already a global trend. Even developing countries have such policies (ASEAN 2008). Our finding suggests that those highly skilled personnel relocate to or stay inside the country.

Lastly, one may raise a concern that the increase in patent filing for the last decades does not reflect the increase in innovation. Rather, it reflects the increase of pro-patent mindsets. We are aware of this issue, and we also assume that our data includes the bias in some extent, i.e. some increase in inventors is due to the increase in patent data available for the analysis. Nonetheless, our data shows that not every country increased their inventors. Some country stayed constantly or decreased. Accordingly, we expect our finding is still meaningful.

Appendix A: Country and Year Information (1975-2010) in each regression

Country	Years in low income	Years in lower-middle income	Years in upper-middle income
Afghanistan	1975-2010		
Albania		1975-2010	
Algeria		1975-2010	
Angola	1975-2010		
Argentina			1975-2009
Austria			1975
Bangladesh	1975-2010		
Benin	1975-2010		
Bolivia		1975-2010	
Botswana	1975-1982	1983-2010	
Brazil		1975-2010	
Bulgaria		1975-2005	2006-2010
Burundi	1975-2010		
Burkina Faso	1975-2010		
Cambodia	1975-2004	2005-2010	
Cameroon	1975-2010		
Central African Republic	1975-2010		
Chad	1975-2010		
China	1975-1991	1992-2008	2009-2010
Chile		1975-1991	1992-2004
Colombia		1975-2010	
Congo		1977-2010	
Congo (Democratic Republic of)	1975-2010		
Costa Rica		1975-2005	2006-2010
Dominican Republic		1975-2010	
Ecuador		1975-2010	
Egypt	1975-1979	1980-2010	
El Salvador		1975-2010	
Eritrea	1975-2010		
Finland			1975-1978
Gabon		1975-2010	
Gambia	1975-2010		
Ghana	1975-2010		
Greece			1975-1999
Guatemala		1975-2010	
Guinea	1975-2010		
Guinea Bissau	1975-2010		
Haiti	1975-2010		
Honduras	1975-2004	2005-2010	
Hong Kong		1975	1976-1982
Hungary		1975-2000	2001-2010
India		2002-2010	
Indonesia	1975-1985	1986-2010	
Iran		1975-2010	
Ireland			1975-1989
Israel			1975-1985
Italy			1975-1977
Jamaica		1975-2010	
Japan			1975-1976
Jordan		1975-2010	

Kenya	1975-2010		
Korea		1975-1987	1988-1994
Laos	1975-2010		
Lebanon		1975-2010	
Lesotho	1975-2010		
Liberia	1975-2010		
Libya		1975-2010	
Madagascar	1975-2010		
Malawi	1975-2010		
Malaysia		1975-1995	1996-2010
Mali	1975-2010		
Mauritania	1975-2010		
Mauritius		1975-1990	1991-2002
Mexico		1975-2002	2003-2010
Mongolia	1975-2010		
Morocco	1975-1976	1977-2010	
Mozambique	1975-2006	2007-2010	
Myanmar	1975-2003	2004-2010	
Namibia		1975-2010	
Nepal	1975-2010		
Niger	1975-2010		
Nigeria	1975-2010		
Oman		1975-1996, 1998-2000	1997, 2001-2010
Panama		1975-2010	
Paraguay		1975-2010	
Pakistan	1975-2004	2005-2010	
Peru		1975-2010	
Philippines		1977-2010	
Poland		1975-1999	2000-2010
Portugal		1975-1977	1978-1995
Romania		1975-2010	
Rwanda	1975-2010		
Saudi Arabia		1975-1978	1979-2010
Senegal	1975-2010		
Sierra Leone	1975-2010		
Singapore		1975-1977	1978-1987
South Africa		1975-2010	
Spain			1975-1989
Sri Lanka	1975-1982	1983-2010	
Sudan	1975-2010		
Swaziland		1975-2010	
Syria		1975-1995	1996-2010
Taiwan		1975-1985	1986-1992
Tanzania	1975-2010		
Thailand	1975	1976-2003	2004-2010
Togo	1975-2010		
Turkey		1975-2004	2005-2010
Tunisia		1975-2010	
Uganda	1975-2010		
Uruguay		1975-1995	1996-2010
Vietnam	1975-2001	2002-2010	
Venezuela			1975-2010
Yemen	1975	1976-2010	

Zambia	1975-2010		
Zimbabwe	1975-2010		

* Countries whose years in upper-middle income end before 2010 entered high income.

Appendix B: Summary statistics of the variables used in each regression

B-1) Regression 1

Variable name	#	Mean	Standard deviation
Patents	2080	5.473901	33.09127
Inventors	2080	16.57644	115.9377
Inventors per million population	1973	0.234554	0.849256
Domestic inventors	2080	14.78942	103.5478
Foreign inventors	2080	1.787019	14.53437
Domestic inventors per million population	1973	0.147205	0.621081
Foreign inventors per million population	1973	0.087349	0.501661
Human capital	1694	1.862499	0.454808
Log(Capital)	1898	24.81226	1.777311

B-2) Regression 2

Variable name	#	Mean	Standard deviation
Patents	1463	19.29536	92.75281
Inventors	1463	48.82228	197.845
Inventors per million population	1388	2.217505	8.531596
Domestic inventors	1463	45.08954	185.1074
Foreign inventors	1463	3.732741	18.04673
Domestic inventors per million population	1388	1.98945	8.352476
Foreign inventors per million population	1388	0.228054	0.724481
Human capital	1324	775.4186	5317.264
Log(Capital)	1342	25.74517	1.557495

B-3) Regression 3

Variable name	#	Mean	Standard deviation
Patents	565	1619.883	5894.107
Inventors	565	3568.083	13386.48
Inventors per million population	565	72.10744	138.7047
Domestic inventors	565	3448.044	13051.83
Foreign inventors	565	120.0389	376.8336

Domestic inventors per million population	565	64.40423	127.8692
Foreign inventors per million population	565	7.703208	21.81771
Human capital	537	2.574814	0.366712
Log(Capital)	565	27.08286	1.372492

Appendix C: Correlation matrix of variables used in the regression

(1) Patent, (2) Inventors, (3) Inventors per million population, (4) Domestic inventors, (5) Foreign inventors, (6) Domestic inventors per million populations, (7) Foreign inventors per million populations, (8) Human capital, (9) Log(Capital), (10) China, (11) India, (12) Korea, (13) Taiwan, (14) Japan

C-1) Regression 1

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
(1)	1										
(2)	0.9779	1									
(3)	0.3333	0.2427	1								
(4)	0.972	0.9976	0.2436	1							
(5)	0.8754	0.8696	0.2008	0.8333	1						
(6)	0.4182	0.3121	0.8108	0.3225	0.1922	1					
(7)	0.0465	0.0244	0.6891	0.013	0.102	0.1345	1				
(8)	0.1066	0.0881	0.2155	0.0835	0.1078	0.1866	0.1336	1			
(9)	0.3677	0.3476	0.1335	0.3498	0.2806	0.2215	-0.0469	0.3441	1		
(10)	0.4042	0.4184	0.0144	0.3988	0.496	0.0276	-0.0098	0.061	0.3294	1	
(11)	0.2728	0.3353	0.0123	0.3624	0.0925	0.0321	-0.0189	-0.0885	0.2677	-0.0151	1

C-2) Regression 2

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
(1)	1												
(2)	0.8952	1											
(3)	0.5591	0.64	1										
(4)	0.9042	0.9978	0.6683	1									
(5)	0.5397	0.7287	0.1607	0.6814	1								
(6)	0.5581	0.6405	0.9965	0.67	0.1489	1							
(7)	0.1498	0.1521	0.2871	0.1455	0.175	0.2065	1						
(8)	-0.0287	-0.0349	-0.0103	-0.0355	-0.0182	-0.0184	0.0915	1					
(9)	0.272	0.3386	0.1174	0.3287	0.3396	0.1244	-0.0527	0.1511	1				
(10)	0.2253	0.391	-0.0184	0.3513	0.6837	-0.0173	-0.0175	-0.015	0.2843	1			

(11)	0.1774	0.3077	-0.0071	0.3164	0.1278	-0.0061	-0.0137	-0.008	0.123	-0.0051	1		
(12)	0.3555	0.287	0.1418	0.2977	0.0934	0.1422	0.0311	-0.018	0.1093	-0.0116	-0.0062	1	
(13)	0.4058	0.2332	0.2832	0.2458	0.0353	0.2858	0.0401	-0.0171	0.044	-0.011	-0.0058	-0.0131	1

C-3) Regression 3

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(14)	(12)	(13)
(1)	1											
(2)	0.8952	1										
(3)	0.5591	0.64	1									
(4)	0.9042	0.9978	0.6683	1								
(5)	0.5397	0.7287	0.1607	0.6814	1							
(6)	0.5581	0.6405	0.9965	0.67	0.1489	1						
(7)	0.1498	0.1521	0.2871	0.1455	0.175	0.2065	1					
(8)	-0.0287	-0.0349	-0.0103	-0.0355	-0.0182	-0.0184	0.0915	1				
(9)	0.272	0.3386	0.1174	0.3287	0.3396	0.1244	-0.0527	0.1511	1			
(14)	0.2253	0.391	-0.0184	0.3513	0.6837	-0.0173	-0.0175	-0.015	0.2843	1		
(12)	0.3555	0.287	0.1418	0.2977	0.0934	0.1422	0.0311	-0.018	0.1093	-0.0116	1	
(13)	0.4058	0.2332	0.2832	0.2458	0.0353	0.2858	0.0401	-0.0171	0.044	-0.011	-0.0131	1

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