Innovation Trends in South Korea

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Abstract—This paper analyzes innovation trends in South Korea by means of the number of patent applications filed by residents and nonresidents during the period 1965 to 2012. Making use of patent data released by the World Intellectual Property Organization (WIPO), we search for the presence of multiple structural changes in patent application series in this country. These changes may suggest that firms' innovative activity has been modified as a result of implementing some science, technology and innovation (STI) policies. Accordingly, the new regulations implemented in this country in the last decades have influenced its innovative activity. The question conducting this research is thus how STI policies in South Korea have influenced its innovation activity. The results confirm the existence of multiple structural changes in the series of patent applications resulting from alternative STI policies implemented during these years.

Keywords—Econometric methods, innovation activity, South Korea, patent applications, science, technology and innovation (STI) policy.

I. INTRODUCTION

THIS paper accounts some results that are part of a larger research project on innovation activity in selected countries [1]. In this case, this paper analyzes innovation activity in South Korea by means of the number of patents granted and patent applications filed by residents and nonresidents during 1970 to 2012. However, the question conducting this research is how STI policy in South Korea during the last decades has affected innovation trends in this country. The objective is thus to test the possibility of finding some structural changes in data series of patents granted and patent applications filed by residents and nonresidents in these countries [2], [3]. From this perspective, the analysis developed in this paper allows testing the possibility of endogenous determining multiple structural changes in patents granted and patent application series in South Korea.

In addition to this introduction, the paper is organized in five sections. Section II discusses the theoretical issues supporting innovation activity and patent granting. Section III analyzes the main features characterizing STI policy in South Korea. Section IV presents an econometric model to test the possibility of finding some structural changes in patent applications series in South Korea. Section V highlights the main results achieved from applying the econometric model discussed in this paper. Finally, Section VI presents some conclusions in relation to this research.

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II. LITERATURE REVIEW

This section reproduces the theoretical framework developed in a previous research [1]. As stated in the Introduction to this paper, the results presented in this paper are part of a research project on innovation activity and structural change in selected countries. However, in these researches, it has been argued that changes observed in intellectual property regimes and science, technology and innovation policy implications over the past decades have moved into the same direction [4]: expanding and strengthening the protection of innovation. The passage of the Bayh-Dole Act in the United States (1980), for example, has intensified these trends in that the legal and administrative changes observed in the United States uncovered the need to adjust other intellectual property regimes in other countries in the world. The outcomes drawn from the new realm in terms of intellectual property have opened up further opportunities to commercialize new knowledge through patents and licenses [5], [6]. Nevertheless, national patent applications have continued to be driven by some factors [7], [8]: (1) firm size, (2) market power, (3) technological opportunity, (4) research efforts, and (5) intellectual property strategies adopted by the firm.

The effect of firm size on national patent applications derives from the Schumpeterian hypothesis suggesting that large firms are more innovative than small firms [9]. Large firms benefit from economies of scale and scope, spillovers and access to financial markets in order to financing risky innovation projects [10]. In some cases, small firms are more likely to patent to compensate for disadvantages in terms of market share and brand name [11]. The relation established between market power and patent applications also derives from Schumpeter's hypothesis in that firms with a higher market power are more innovative than firms with weak market power [9]. Even if this factor has also been controversial, there is evidence of a positive impact of firm's market power on its innovation activity [12], [13]. Technological opportunity is defined as the extent to which an industry relies on science-based research [13]. In consequence, firms in high technology opportunity sectors are found to patent more than other firms [11]. The relation established between research efforts and patent applications goes from R&D to patents, as a process that affects firms' innovative performance. In this sense, the relationship between R&D and patents can be seen as a virtuous cycle that requires further development costs in order to reach the market [7]. Finally, in relation to the intellectual property strategy adopted by firms, there are also many factors influencing their innovative capabilities, such as the relative importance of basic and applied research in total R&D, the product or process

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orientation of innovation efforts, the extent to which R&D is jointly performed with other institutions, and the limitations and inefficiencies of the patent system [7]. In this sense firm's patenting behavior might correlate with the type of innovation strategy pursued, the perceive barriers to the innovation process (internal, external, risk and cost-related barriers), and the limitations of the patent system they recognize [7].

III. STI POLICY IN SOUTH KOREA

Since the emergence of the knowledge-based economy, science and technology has been recognized as an important engine for successfully innovate by firms. In fact, many scholars have stressed the importance of co-evolution of science and technology, on the one hand, and innovation developments, on the other [14]-[16]. In fact, the fundamental resource for developing competitive advantages in modern economies is knowledge [16]-[18]. In the case of emerging economies, knowledge-based innovations and human resources training are both required to transit into the development of innovation capabilities.

Therefore, any successful science, technology and innovation policy aiming to support science and technology developments for improving innovation should take into account its role as accelerating productivity factor, and as a source of value in the economy. A science, technology and innovation policy should be a way for preventing a sustainable economic development. Such a policy may follow at least three objectives: (1) to develop R&D capabilities at public institutions for research and universities, (2) to stimulate firms' demand for scientific and technological knowledge through establishing close relations between universities, firms, and governments, and (3) to support and develop national innovation systems in countries.

In the case of South Korea, as well as some other Asian economies, the high growth rates have been explained from two alternative perspectives [19]: the accumulation view of growth and the assimilation view. The accumulation view of growth suggests that high savings and investments have made possible to better use technologies inherited from investments of technological leaders [19]. On the other hand, the assimilation view suggests that critical source of growth in these countries has been productivity growth resulting from learning, entrepreneurship and innovations in these countries [19]. In fact, this approach has made possible the adoption of foreign technologies and thus the development of indigenous technologies [19].

An adequate way of analyzing innovation activity is through patent granting and applications. In the last decades, patenting activity in many Asia countries has significantly increased. These trends have allowed South Korea to develop fast-growing industries achieving a higher degree of specialization [19]. In this sense, it would be expected that as national economies become globalized, firms in these countries may search for patenting abroad. Table I shows patents granted to some selected countries in Untied States. In the case of South Korea, this table suggests how innovation activity has improved in the 1990s.

TABLE I
PATENTS GRANTED TO ASIAN COUNTRIES IN UNITED STATES [19, p.1034],

Country	1970-74	1975-79	1980-84	1985-89	1990-94	1995-99
Taiwan	1	176	397	1,772	5,271	12,366
SouthKorea	24	43	91	424	2,890	11,366
Hong Kong	59	75	113	177	279	570
Singapore	21	9	20	47	148	499

However, these trends can be explained from applying a successful science, technology and innovation policy in this country. In this sense, the national innovation system in South Korea is characterized by heavily invested in human capital, education, science and technology, and knowledge development [20].

In this sense, South Korea government has played an important role guiding education and corporate R&D, developing a robust science and technology capacity [20]. In short, the role of the South Korea government has been to support the development of industry-oriented research centers allowing developing a platform and infrastructural technologies to enable of subsequent creation of other products and processes [20]. On the other hand, the business conglomerates (chaebols) in this country have allowed moving from safe technology investments and incremental innovations toward cutting-edge science-based innovation through investing in R&D for improving its service sector [20].

As a result, the plans implemented by the South Korea government during the 1990s and 2000s improved the capacity and funding for R&D, developing an R&D workforce and increasing funding for basic science [20]. In turn, these policies allowed increasing R&D intensity, rising patents and academic publications, and increasing high-technology exports [20].

TABLE II
PATENT APPLICANTS IN SOUTH KOREA [20]

Applicant	Number of Patent Applications
LG Electronics Inc.	1,094
Samsung Electronics Co., Ltd	683
LG Chem Ltd	352
LG Innotek Co., Ltd	227
Electronics & Telecom. Research Inst. of Korea	116
Pantech Co., Ltd	110
Seoul National University	101
Korea Advanced Institute of Science and Technology	82
Cheil Industries Inc.	77
Korea Research Institute of Bioscience and Biotechnology	76

Table II shows the main companies patenting in South Korea. This table demonstrates that the main actors patenting in South Korea are in high-technology innovation sectors (e.g. telecommunications and biotechnology) [20]. However, the most important sectors in South Korea are in electronic integrated services, shipbuilding, automobiles, and petroleum refining [20]. In this regard, in this country, intellectual property (patents) along with government policy on export orientation and competitiveness in science and technology related sectors have moved South Korea to the top ranks in

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terms of exporting high-technology products [20].

In short, innovation in South Korea is primarily driven by the private sector, which is dominated by the top conglomerates such as Samsung, Hyundai, POSCO and LG [20]. Actually, these four conglomerates dominate private spending in R&D in this country [20].
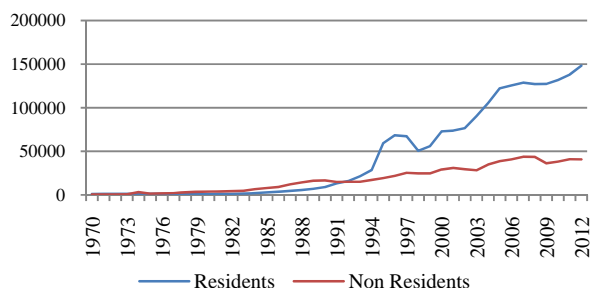

Fig. 1 South Korea: patent applications, 1970-2012

From an overall perspective, the number of patent applications and patents granted in South Korea illustrates innovation activity in this country. Even if many scholars suggest that patents are not the most suitable indicator for innovation activity, patents continue being used as an important indicator of innovation analyzed by researchers. In the fowling, the number of patent applications and patents granted are analyzed in the case of South Korea (Figs. 1 and 2). It is important to keep in mind that the analysis of indicators, patent applications and patents granted, is developed through using data released by the World Intellectual Property Organization (WIPO).

Fig. 1 shows the number of patent applications of residents and nonresidents from 1970 to 2012in South Korea. An important feature in Fig. 1 is that the number of patent applications of residents increased dramatically in 1990s and 2000s. Moreover, the number of patent applications during these decades increased faster than the number of patent applications of nonresidents in this country.
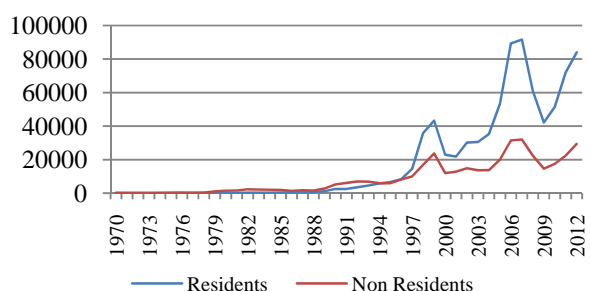

Fig. 2 South Korea: patents granted, 1970-2012

On the other hand, Fig. 2 shows the number of patents granted to residents and nonresidents from 1970 to 2012in South Korea. Fig. 2 also demonstrates an important growth in the number of patents granted to residents and nonresidents during this period in this country. The trend observed in these series demonstrates to be more cyclical than in the case of

patent applications. This behavior can be explained as a result of the time it takes for patent applications to be granted. Nevertheless, in South Korea, the number of patent granted to residents is much more important than the number of patents granted to nonresidents during the 1990s and years after.

The objective in this research is thus to test for the possibility of finding one or more structural breaks in the series of patent applications and patents granted to residents and nonresidents in South Korea from 1970 to 2012. This possibility may suggest that science, technology and innovation policy implemented in this country during this period was successful to boost innovation capabilities among firms to compete in markets.

IV. ECONOMETRIC METHODS AND MODEL

This paper analyzes the possibility to find one or more structural breaks in the series of patents granted and patent applications filed by residents and nonresidents in South Korea. It is expected that these results may explain how the results derived from the new dispositions implemented in this country in relation to the science, technology and innovation policy during the last decades and its intellectual property regime might affect innovation capabilities among firms.

Structural change or structural instability has been interpreted as a change in the regression parameters [21]. In the case of patents granted and patent application series, the structural stability hypothesis can be rejected when it is observed a change into a prevailing regime [22]. The existence and time location of a structural change can be econometrically tested through an autoregressive statistical time series dynamic model of order one AR(1) as follows [23]:

$$Y_t = \alpha + \rho Y_{t-1} + e_t \tag{1}$$

$$\sum_{t=1}^{n} e_t^2 / (n-k) = \sigma^2 \tag{2}$$

Y_t in (1) represents a time series, and Y_{t-1} is the same time series lagged one period. It is assumed that the error term e_t is not serially correlated. Equation (2) represents the formula for estimating the variance, where the term in the numerator is the sum of squared errors and the term in the denominator are the degrees of freedom [24]. When one or all parameters of the model change at some point in time in the sample, it is possible to say that a structural break has occurred. The possibility to find structural breaks in the series of patents granted and patent applications filed by residents and nonresidents in South Korea results from the regulatory changes implemented in this country derived from the science, technology and innovation policy and its intellectual property regime during the 1990s and 2000s. In this research, to test for structural breaks, patents granted and patent application data released from WIPO is used. Table III shows the definition of variables used in this model to test for one or more structural

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breaks in the series of patents granted and patent applications filed by residents and nonresidents in South Korea.

TABLE III
VARIABLES DEFINITION

Variable	Definition
PTKRAR	Rate of growth of patent applications by residents in South Korea
PTKRAN	Rate of growth of patent applications by nonresidents in South Korea
PTKRGR	Rate of growth of patents granted to residents in South Korea
PTKRGN	Rate of growth of patents granted to nonresidents in South Korea

The model in this research was estimated using the growth rates of the number of patents granted and patent applications filed by residents and nonresidents in South Korea. The model used to test for multiple structural breaks was specified following a multiple linear regression with m breaks (m+1 regimes), where all coefficients are subject to change:

$$y_t = z_t' \delta_j + u_t \qquad (t = T_{j-1} + 1, ..., T_j)$$

$$\text{for } j = 1, ... m+1, \; T_0 \text{ and } T_{m+1} = T$$

In this case, y_t is the observed dependent variable, $z_t (qx1)$ is a covariance vector, $\delta_j (j = 1, ..., m+1)$ is the corresponding coefficients vector, and u_t is a disturbance term. The parameter m indicates the number of breaks. The break points $(T_1, ..., T_m)$ are explicitly treated as unknown. The estimation methods used in this research is based on the least square principles [25]-[26]. For each m-partition $(T_1, ..., T_m)$, denoted as $\{T_j\}$, the associated least squared estimated of δ_j is obtained by minimizing the sum of the squared residuals $\sum_{i=1}^{m+1} \sum_{t=T_{i-1}+1}^{T_i} [y_t - z_t' \delta_t]^2$ constrained to $\delta_i \neq \delta_{i+1} (1 \leq i \leq m)$. Let $\delta[\{T_j\}]$ to be the resulting estimations. Substituting it into the objective function and denoting the resulting sum of squared residuals as $S_T(\hat{T}_1, ..., \hat{T}_m)$, the estimated break points $(\hat{T}_1, ..., \hat{T}_m)$ are such that:

$$(\hat{T}_1, ..., \hat{T}_m) = \arg \min_{T_1, ..., T_m} S_T(T_1, ..., T_m)$$

where the minimization is taken over all partitions $(T_1, ..., T_m)$, such that $T_i - T_{i-1} \geq q$. Thus, the break point estimators are global minimizes of the objective function. Finally, the regression parameter estimates are the associated least-squares at the estimated m-partition $\{T_j\}$, i.e. $\hat{\delta} = \delta[\{T_j\}]$.

In this research, $AR(k)$ models were applied for each variable. The appropriate number of lags was determined using Ng and Perron methods [27], and estimating an $AR(k)$ process using the maximum value k_{max}. If the latest lag was not significant, then the selection of k was reduced by one. This process continued until the latest lag was significant or k=0. In this case, 5 was taken as the maximum value of k and

the significance of the lags was evaluated using the critical value of 10% of the normal standard distribution. To determine the number of structural breaks, the Bayesian Information Criterion (BIC) was used [28]. The number of estimated structural breaks $\hat{m}$ was determine by minimizing the above-mentioned information criterion give a fixed upper bound for m, $M = 5$.

V. RESULTS

From an overall perspective, the results achieved in this research suggest that the science, technology and innovation policy implemented in South Korea during the 1990s and 2000s has been successful to develop indigenous innovation capabilities among firms (Table IV).

TABLE IV
BREAKING YEARS IN PATENTS GRANTED AND PATENT APPLICATIONS IN SOUTH KOREA

Residents			Non Residents		
Variable	Breaking Year	BIC	Variable	Breaking Year	BIC
PTKRGR	1988	-2.142	PTKRGN	1988	-2.142
	1992			1992	
PTKRAR	1977	-3.691	PTKRAN	1967	-3.810
	1994			1973	
	1996			1975	
	1998			1989	

However, this policy has been more successful in the case of patent applications filed by residents in the 1990s. In this sense, 1994, 1996 and 1998 are breaking years in the case of patents applications filed by residents, reflecting the development of a more entrepreneurial attitude among inventors in South Korea. On the other hand, in the case of patents granted to residents in 1990s in this country, the only breaking year is 1992. This can be explained given that it could take some time to get patent after filing a patent application.

Finally, in the case of nonresidents, patenting activity is less important in South Korea during the decades analyzed in this paper. Even if both series do not demonstrate structural break, Figs. 1 and 2 suggest a greater number of patents granted and patent applications in South Korea. The reason explaining this behavior could be that South Korea has become a more globalized economy.

VI. CONCLUSIONS

This research aimed to test the possibility of finding structural changes in patents granted and patent applications series of residents and nonresidents in South Korea. The use of the econometric methods in this paper allowed endogenously determining the existence of structural breaks in these series. The results achieved in this research demonstrate that science, technology and innovation policy in South Korea in the last decades has been successful to boost indigenous innovation capabilities in this country.

From the perspective of econometric methods, this research demonstrated how structural breaks could be determined endogenously. In this research, this possibility allowed

determining the possibility of finding adequate science, technology and innovation policies to support the development of innovation capabilities in South Korea.

Further research should be done in relation to the interface between science, technology and innovation policy, and strategy among innovative firms in South Korea. The analysis of capability developments in South Korea firms may contribute drawing interesting lessons to other technology-based companies. In the same way, lessons learned from science, technology and innovation policy implemented in South Korea during these decades may contribute to analyze science, technology and innovation policies in other countries.

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