India's Patent Surge and Tech Specialization: Narrowing the Innovation Gap with Triad Economies

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Abstract— **Over the last two decades, India has experienced remarkable growth in intellectual property (IP) filings. According to the World Intellectual Property Organization (WIPO) data, India achieved a global ranking of 7th in patents and 3rd in trademarks in 2018. This accomplishment is significant given the country's historically low demand for IP protection. The paper delves into detailed analysis of IP adoption trends in India, China, and Korea, emphasizing the structure of patent demand since 1999. It breaks down and analyses available patent data according to patent applications filed by designated countries across various IP systems both international and national, and under various technology classes. Furthermore, the paper explores India's potential to catch up with the triad economies (US, Japan, and EU) in terms of intellectual property rights (IPR) utilization, considering the existing momentum in IP registrations both domestically and abroad.**

Index Terms— **IPR, Patent Filings, Catch-up, Technology Specialisation, India JEL Classification: O3, O30, O31, O32**

I. Introduction

India is experiencing a historical take-off in the usage of intellectual property rights (IPR). In particular, there has been a notable upward trend in the patent activity over the past two decades. Despite being just behind leading patent user countries such as China, the US, Japan, EU, and Korea, India has secured the 7th rank among the top ten patent-filing nations globally. In 2018, the national patent office (IPO) received 50,055 applications, indicating a 7.5% growth compared to the 46,582 applications filed in 2017. This growth surpassed the global average, which saw a 5.2% increase in patent applications in the same year (IPO 2018).

This paper primarily aims to examine the trends in IPR uptake in India. However, it also analyses and compares IPR trends in other emerging economies such as China and Korea with those of advanced triadic economies. The detailed analysis focuses on the surge in patenting activity, highlighting the structure of patent demand since 1999. The data on patent filings is segregated and analysed according to: (i) patent filings by designated countries across different international, regional, and national patent systems; and (ii) patent filings by these countries under various technology classes. Besides analysing the existing momentum in IPR registrations across various IP systems[1], the paper addresses the question of India's potential catch-up with advanced economies, such as the US, Japan, and the EU. Implicit in this discussion is the consideration of whether the current trends in IPR uptake in India signify an innovative effort enabling specific segments of the economy to rapidly advance and keep pace with cutting-edge technology.

The paper is structured into seven sections. Section 2 deals with the economic progress of India and discusses several aspects of that might affect future sustainability. Section 3 addresses the historical dynamics of IPR take-up, questioning the correlation between patent filing trends and innovation. Section 4 introduces several methodological considerations concerning the data used and analyses carried out. Sections 5 and 6 are dedicated to empirical analysis of patent filings in various systems and addressing issues related to technological specialization. Lastly, Section 7 offers conclusions and outlines directions for future research.

II. To what extent will India succeed in its IPR catch-up endeavours?

Since the initiation of the 1991 reforms, India's economic performance has been outstanding, with notable acceleration in both aggregate GDP and per capita GDP. Over the last decade, per capita growth has averaged 5.5 per cent annually, a unique feat when compared to some of the world's largest emerging economies. This impressive growth rate can be partly attributed to the export of services. India has excelled in service exports. Notably, India's share in world services trade is close to 3%, three times higher than its share in goods exports. As highlighted by Baldwin (2006), China benefited from global production delocalization, while India drew strength from the dissemination of information and communication technologies (ICT).

In contrast to economic growth, R&D investment in India has progressed slowly, with a GERD/GDP ratio below 1%, notably lower than countries like the US, Japan, China, and Korea, where R&D expenditure ranges between 2-3% of GDP. Additionally, India lags in the proportion of its workforce dedicated to research activities (Table 1). Despite these challenges, India's recent performance in IPR filings stands out. Patent applications originating from India have surged not only at the IPO but also across various international and national patent systems, including PCT, EPO, and USPTO. Figure 1 illustrates dynamic trends in

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[1] These IP systems include various national, regional and international IP systems such as the United States Patent and Trademark Office (USPTO), European Patent Office (EPO), Japan Patent Office (JPO), China National Intellectual Property Administration (CNIPA), Korean Intellectual Property Office (KIPO), Indian Patent Office (IPO), and Patent Treaty Corporation (PCT) system.

total patent applications, signalling a significant shift in the global geography of innovation toward emerging economies, such as India, China, and Korea.

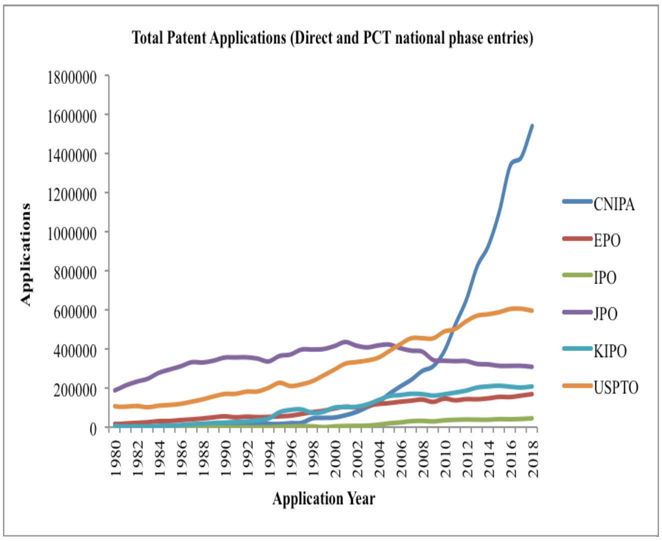
Recent patenting trends suggest that emerging economies like China and India may be on an economic catching-up trajectory, not just in terms of GDP per capita but also in innovative capacities. While empirical research often focuses on the growth convergence of nations based on their varying GDP levels, little attention has been given to the possibility of IPR catch-up by emerging economies with advanced ones. This paper explores this aspect by analysing the growth in demand for Indian patents (by residents and non-residents) and comparing it with patent filing growth at leading PTOs globally. The IPR dimension of the catching-up process could have significant implications for innovation, new technology, and product use in emerging economies. Moreover, patenting upsurge in India, accompanied by extensive trademark usage, could denote a crucial juncture in the country's development. These observed trends might function as robust indicators of the sustainability of economic growth in India, potentially facilitating an effective catch-up in economic terms.

Table 1: R&D Expenditure, R&D Personnel and Resident Patent Filings.

R&D Expenditure (% of GDP)						
	1995	2000	2005	2010	2015	2018
China	0.56	0.89	1.31	1.71	2.07	2.17
India	0.64	0.76	0.82	0.81	0.62	0.60
Japan	2.69	2.91	3.18	3.14	3.28	3.27
Korea	2.26	2.18	2.63	3.47	4.22	4.88
USA	2.45	2.63	2.52	2.74	2.72	2.82
EU	1.70	1.75	1.78	1.97	2.12	2.18
Researchers in R&D (per million people)						
	1995	2000	2005	2010	2015	2018
China	438	539	841	885	1151	1253
India	152	110	135	156	216	253
Japan	4875	5078	5304	5104	5173	5399
Korea	2173	2287	3692	5331	7013	7909
USA	3141	3496	3743	3885	4267	4300
EU	1968	2123	2601	3092	3527	3979
Resident applications (per million People)						
	1995	2000	2005	2010	2015	2018
China	8	20	72	219	706	1001
India	2	2	4	7	10	12
Japan	2661	3029	2880	2265	2036	2005
Korea	1313	1549	2536	2660	3279	3148
USA	466	584	703	782	899	871
EU	170	224	191	214	190	201

Source: Data on R&D comes from the World Bank, and data on Patent applications is compiled from WIPO.

Figure: Trends in patent filings at selected patent offices, 1980-2018



Source: WIPO statistics database

III. Patenting and Innovation Nexus

A patent is an exclusive right granted to innovators for a new product or process, allowing them a monopoly over the invention for about 20 years. During this period, commercial use or sale without the patent owner's consent is prohibited. Patents are commonly used by researchers to gauge both the volume and value of innovation. Patent counts indicate the extent of innovation, and frequently cited patents are indicative of higher technology and economic value (Dang & Motohashi, 2015). In the 1960s, Schmookler and Scherer proposed employing patent statistics to evaluate the rate and direction of inventive activities (Scherer 1965; Schmookler, 1966). Since then, patent statistics have widely served as indicators of innovation, with new patent numbers reflecting innovation levels. Several studies highlight the advantages of using patent statistics for innovation indicators: (i) patents offer rich and timely information on inventive activities, closely linked to new technology development; (ii) patent data as an innovation proxy is more accessible than alternatives like R&D and total factor productivity; (iii) patent analysis facilitates understanding of knowledge flows through citation analysis; and (iv) patent data allows for cross-country comparisons (Marzal and Tortajada, 2007; Dang and Motohashi, 2015). According to EPO estimates, approximately 50% of innovations are patented (EPO, 1994, p. 25). Jaffe (1989), Acs and Audretsch (1993), and Acs et al. (2002) find no significant differences between patents and actual innovations as two output indicators of innovation.

While patent statistics offer valuable information on innovation, caution is warranted, as emphasized by various authors (Pavitt, 1988; Griliches, 1990; Trajtenberg, 1990; Archibugi, 1992). This measure can be misleading due to: (i) country-specific variations in the economic costs and benefits of patenting, including enforcement mechanisms, examination rigor, and market size; (ii) differences in the importance of patents as an appropriability tool across technologies and sectors; and (iii) variations in firms' propensity to patent, especially evident between traditional SMEs and larger firms, reflecting sector-specific patent demand disparities (Levin et al., 1987; Marzal and Tortajada-Esparza, 2007).

Despite the limitations of using patents as innovation indicators, interest in them has grown significantly, particularly in the era of "intellectual capitalism" in the global north (Grandstrand, 1999). This heightened attention follows the "patent boom" or "patent explosion" (Hall, 2005), partly driven by the growth of R&D-intensive sectors like microelectronics, ICT, and biotech in advanced economies (Kim and Marschke, 2004). The surge in patenting can be also tied to a strategic use of patents. New firms deploy patents to signal innovation, while established firms build extensive IPR portfolios to avoid litigation and leverage cross-licensing and technological negotiations (Harabi, 1995; Duguet and Kabla, 1998; Hall, 2005).

Several studies have been undertaken on the rising demand of IPRs in the global south specifically in relation to China and India. Hu and Jafferson (2009) attribute the surge in patenting to FDI inflows and, to some extent, a legal framework favouring patent holders. They note, however, that the rise in R&D expenditure in China does not align with the growth in patenting activity. As India began complying with the TRIPS agreement, it already had a well-established, low-cost pharmaceutical industry producing generic drugs. Although imitation and reverse engineering may not lead to innovation, they are crucial for learning and acquisition (Katz and Shapiro, 1987). These developments have enabled Indian firms to cultivate innovative capabilities and increase their IPR uptake. However, concerns linger about the quality of patents granted by the IPO and CNIPA. This is backed by low citation ratio[2] of the patents issued by these countries.

A pertinent research question regarding the patent surge in emerging economies is whether it shares the same underlying reasons as in advanced economies or if distinct factors drive the observed trends. This paper aims to address this question by examining India's patent specialization, specifically determining if the increase in patent usage occurs across different technology fields at the same intensity as in advanced economies.

IV. Methodology and Data

The main challenge in using patent data to assess innovation is home bias. Domestic firms often prioritize protection in their home markets, leading to a higher volume of patent filings with their national patent offices. This bias makes international comparisons of patent filings inappropriate. Patel and Vega (1999) noted this issue concerning US domestic users of USPTO patents. While many studies advocate using USPTO patents for international comparisons since US is the most dynamic technological market globally. Innovations with significant market potential, regardless of their geographical origin, often seek protection in the US. However, caution is needed to avoid direct comparisons between patents filed by US residents at USPTO and those filed by foreigners. An alternative to using USPTO data is to utilize triadic patent statistics[3]. However, an issue with the latter is its availability with a certain time lag.

Given the challenges associated with USPTO and triadic patent statistics, this study analyses the surge in IPR activities utilising the data on so-called "international (or PCT) patents and European (or EPO) patents." Since its inception in 1978, the PCT system has matured, expanding its geographic span from 13 countries initially to 153 contracting states in 2020. A single filing under the PCT agreement provides coverage in many different countries, establishing it as a truly global system. It has exhibited an average annual growth rate exceeding 8% over the last two decades. In total, more than 3.7 million PCT applications have been filed since 1995, with consistent annual growth, except for 2009 during the global financial downturn. The PCT review report for 2019 highlights a steady increase in applications year-on-year, reaching a quarter of a million in 2018 (253,000), up from an estimated 243,500 international patent applications filed in 2017. This represents an annual increase of 4% and marks the tenth consecutive year of growth.

Many studies have also utilized European patents granted by the EPO. EPO patents share characteristics of both national and international systems, and when comparing European countries, there is no reason to be concerned about any "home bias" (Criscuolo, 2006). As an alternative to PCT or EPO patents, researchers have the option to simultaneously draw on data stemming from several national patent offices.

In addition to analysing India's patent applications with PCT and EPO systems, this paper also incorporates data from national patent systems (IPO, JPO, CNIPA, and USPTO) to compare patenting trends over the two most recent decades (1999–2008 and 2009–2018). Due to

[2] Citation ratios are an important measure to accessing patent quality (Bloom and Van Reenen, 2002). The citation ratio is defined as the average number of a country's patents cited in subsequent patents. The underlying assumption in using patent citations to measure patent quality is that frequently cited patents probably involve significant technological advances. Tseng (2009) points out that patent quality is extremely heterogeneous in China and India, with most patents being of a lower quality, as indicated by an average citation ratio of 3.6 which is the same for both countries.

[3] Triadic patents are families of patents with the same priority date and filed at the USPTO, the JPO (Japanese Patent Office) and the EPO (European Patent Office).

variations in access and data availability, series lengths may differ across patenting systems. Data for Indian residents are compared with their counterparts in the US, Japan, EU, and, whenever possible, China and Korea.

The technology specialization analysis, focusing on the technology fields of the designated countries, is carried out using patent data from the IP-5 patent families[4]. Following Godinho and Ferreira (2012), the employed technology index assesses the relationship between a country's share of patenting in a specific technology field (*s*) and the global share for all countries. The technology specialisation index (TSI) for country *i* in the technology field *s* can be written as:

$$TSI = \frac{P_{is} / P_i}{P_s / P} \qquad (1)$$

The notations in (1) can be defined as: $P_{is} = \sum_j P_{isj}$ = the sum of individual patents *j* belonging to technology class *s* filled by country *i*; $P_i = \sum_s P_{is}$ = patents of country *i* in all technology fields, i.e. all the patents in country *i*; $P_s = \sum_i P_{is}$ = all countries patenting or world patenting in the technology sector *s*; and $P = \sum_s P_s$ = sum of all patenting, i.e. sum total of world patenting across all technology sectors.

To determine whether a country is "specialized" or "not specialized," Chi-square measure of sectoral specialization is calculated, a measure previously employed by Anderson and Ejermo (2006), Laursen (2000), and Archibugi and Pianta (1992, 1994) for analysing export and technology specialization patterns and their temporal co-movement. This measure is a ratio, where the numerator is the square of the difference between the relative importance of class *s* in country *i* and the relative importance of that class in the world. The denominator is the sum of the weighting of all classes in country *i*, and this ratio is summed across all s classes. The Chi-square of sectoral specialization increases with the specialization intensity of a country and is calculated as follows:

$$\chi_i^2 = \sum \left(\frac{\left[\left(X_{si} / \sum_s X_i \right) - \left(\sum_s \sum_i X_{si} \right)^2 \right]}{\left(\sum_i X_{si} / \sum_s \sum_i X_{si} \right)} \right) \qquad (2)$$

The magnitude of the chi-square measure reflects the extent to which a country is specialized. A country with a patenting structure similar to the rest of the world would have a chi-square indicator value of zero. The greater the difference between a country and the rest of the world in terms of patenting structure, the higher the value of the chi-square measure. Over time, this measure indicates changes in the degree of specialization for each country.

[4] IP-5 patent families refer to patents that have been filed in at least two IP offices worldwide, one of which among the Five IP offices (namely the European Patent Office, the Japan Patent Office, the Korean Intellectual Property Office, the US Patent and Trademark Office and the State Intellectual Property Office of the People Republic of China).

Before delving into data exploration in subsequent sections, some clarifications related to the data are necessary. Firstly, the data utilized in this paper pertains to patent applications rather than patent grants. While application counts are employed as an alternative to grants, this choice is not expected to significantly impact the study's conclusions due to the high correlation between applications and grants. The use of application data offers an advantage in providing a more up-to-date assessment of contemporary patenting trends across countries, especially when compared to grant data, which typically exhibits a time lag of up to a minimum of three years between applications and grants. Differences in patent procedures among offices result in substantial variations in pendency periods (e.g., average pendency time at IPO is about 64 months, whereas it is 14.6 months at JPO), making cross-country IPR comparisons based on patent grants challenging. Additionally, it's essential to note that the PCT system is not a granting system; it solely facilitates the submission of applications to be granted by the patent offices of the contracting states.

The second clarification concerns the variation in patent demand across countries. This variation arises from the significant differences in the quality of patents issued and the requirements of formal examinations conducted beforehand in various national and international patent systems, potentially influencing the propensity to patent in different IP systems. However, by precisely analysing data from these different systems, the derived cross-sectional perspective should provide control over this source of variation in patent demand.

The final clarification pertains to IPR catching up. In this paper, the catch-up analysis should be interpreted as India's ability to match the triadic economies in terms of the quantitative demand for patents. By considering the actual trends in patenting over the last two decades and evaluating the compound annual growth rates of each series, the paper seeks to estimate the time period India requires to reach patenting levels similar to the triadic economies.

V. Analysis of Patent demand at Various PTOs

Information provided in section 2 (Table 1 & Figure 1) highlights a continuous and substantial increase the gross demand for patents, originating from both residents & non-residents, across diverse IP systems/PTOs since the 1980s. This historical trend not only persisted but has also grown more pronounced in recent decades. It is thus intriguing to examine in greater detail the patent demand in each the relevant national IP system, including the US, Japan, China & India, as well as within regional system such as EPO and the international PCT system.

The study begins by analysing patent demand in the international PCT system, which stands out for allowing simultaneous protection of inventions across all contracting states. This feature eliminates the need for multiple applications for the same invention, contributing to higher growth rates in PCT filings compared to regional and national IP systems. From 1999-2018, Chinese demand for PCT filings grew annually at 30%, while Indian and Korean demand each experienced a growth rate of 16%. Triadic economies saw rates in the range of 3-10%. Despite the notable growth rates for China, India, and Korea, their accumulated PCT applications still fall behind those of triadic economies (Table 2).

Certainly, what stands out for China, Korea, and India is the remarkable increase in the number of PCT filings from 1999 to 2018. China, in particular, multiplying its PCT patent applications by over 190 times, while India and Korea each experienced an almost 20-fold increase. A similar trend is observable in absolute demand and growth across all other IP systems, generally with lower annual rates. Nevertheless, demand from China and India, and to a certain extent, South Korea, for triadic patents (patent applications filed with EPO, USPTO, and JPO) has been growing at annual rates in the range of 10–32% over the past two decades. As shown in Figure 1, world demand for Chinese and Indian patents has exhibited significant trends since the early 21st century, particularly post-2004-05, with filings at CNIPA and IPO surging at a faster pace. While the world demand for patents filings at USPTO, EPO, and JPO has risen in the range of -1 to 4% annually, the corresponding rates of patent demand in CNIPA and IPO are much higher, ranging between 19-12% (Table 2). The figures for Chinese filings with IPO and Indian filings with CNIPA suggest that the patenting activity of both countries in each other's PTOs has remained relatively low in absolute numbers, with China's applications reaching nearly 3 thousand and India's just 327 in 2018. Nevertheless, in terms of annualized growth, Chinese filings with IPO have experienced a rate of 26%, and Indian filings with CNIPA witnessed a 19% rise during the period 1999-2018.

Table 2: Patent demand in various (national, regional and international) patent systems

	Initial & recent year		Cumulative sum over 2-periods		Annualized growth rates (%)		
	Y_0	Y_1	P_1	P_0	Y_1/Y_0	P_1/P_0	Reg. Est.
	1999	2018					
PCT							
China	276	53399	24814	302305	30	27	29
India	101	2013	6086	20238	16	12	12
Japan	7474	49706	189092	606831	10	12	9
Korea	870	16919	39397	167474	16	15	15
US	31263	56218	442003	979378	3	8	2
EU	24628	49303	361347	827178	4	8	3
World	76357	252781	1235642	3299275	6	10	5
EPO							
China	35	9416	4792	54376	32	26	33
India	24	701	2017	7607	18	14	20
Japan	14617	22569	196212	412665	2	8	2
Korea	426	7280	24810	83801	15	13	14
US	25333	43740	319406	701664	3	8	2
EU	37581	66245	495582	1112500	3	8	2
World	89359	174397	1197483	2735394	3	8	3
USPTO							

China	251	32615	19176	200869	28	25	27
India	269	9860	13387	80021	20	19	20
Japan	46951	85322	654983	1510325	3	9	3
Korea	5007	33961	134888	456963	10	13	12
US	149251	285095	1956867	4675876	1	9	3
EU	33659	74940	435337	1127934	4	10	5
World	265763	597141	3651132	5542221	4	5	4
JPO							
China	62	5325	2995	29114	25	24	28
India	11	260	927	3055	17	12	15
Japan	357531	253630	3594979	6325663	-2	6	-2
Korea	2186	5070	46282	98710	4	8	3
US	8843	23121	165831	404746	5	9	6
EU	6718	15938	126213	290862	4	9	5
World	404457	313567	4145272	7447447	-1	6	-2
CNIPA							
China	15626	1393815	796813	8588945	25	25	27
India	10	327	1029	3442	19	12	15
Japan	8619	45284	219388	612211	9	11	8
Korea	1427	13875	52001	158322	12	11	11
US	11043	38859	146700	464764	6	12	9
EU	9670	32669	135261	410215	6	11	8
World	50044	1542002	1400160	10402406	19	21	21
IPO							
China	29	2859	1604	15926	26	24	29
India	2206	16289	40051	154297	11	13	11
Japan	417	4676	12375	60373	13	16	15
Korea	93	2321	4056	15935	17	14	17
US	936	10023	53106	155496	13	11	11
EU	529	8674	44858	139014	15	12	1
World	4826	50055	190840	624372	12	12	11

Source: WIPO Statistics Database

Like China, India has bolstered its engagement in the international patent system. Demonstrating remarkable growth in PCT applications, India is gradually catching up and fostering innovation. While India's patent count across various IP systems is currently lower in absolute terms compared to the US, China, and other selected economies, the rapid increase in India's patent demand suggests the potential for convergence with leading IP user economies. In essence, if India sustains the current growth rates observed over the past two decades, catching up with triadic economies in patent volumes is foreseeable within a few decades. Looking at growth estimates from Table 3, future projections suggest that India may catch up with the US in the PCT system in approximately 2.5 decades, while China is anticipated to achieve this in less than a year. India's patent filings at USPTO, EPO, and JPO, are projected to reach current US filing levels in 18, 22, and 30 years, respectively. The US is chosen as the benchmark for this analysis, given its leading position in the PCT, EPO, and USPTO.

Table 3: Average time Span (in years) to catch-up with US at major PTOs

Main Patent Systems				
	PCT	EPO	USPTO	JPO
India	25	22	18	30
China	0.6	06	02	06
Korea	09	16	18	50

Source: Own calculations incorporating respective regression estimates (last column, Table 2) in compound interest formula.

VI. Analysis of Technology Specialization Patterns

The analysis in this section aims to highlight broad patterns of IPR specialization, examined through chi-square coefficients of specialization and RCA index. Form the chi-square ratio reported in table 4; it is evident that China and India exhibit a higher degree of specialization. However, as these economies have evolved over the last two decades, they have transitioned to lower levels of specialization by becoming more competitive across a broader range of products and technologies. The available data indicate that levels of technological specialization have remained relatively stable for the EU, Japan, and the US in the two most recent decades. In contrast, the chi-square coefficients of specialization have declined in the other selected economies, a trend particularly pronounced in the case of India and to some extent in China and Korea.

Table 4: Technological Specialization (chi-squared ratio)

PCT Patent Filings	2000-09	2010-19
India	1.32	0.83
China	0.45	0.36
Korea	0.29	0.11
Japan	0.12	0.14
USA	0.05	0.08
EU	0.09	0.16

Source: Own Calculations based on PCT filings of the designated countries.

Based on PCT filings, Table 5 reports the RCA values for the designated countries. The table establishes a relationship between patent classes (as given by the IPC classification) and industrial sectors (NACE Rev. 2 on the 3-digit level). The mapping of technology sectors to industrial sectors has been made possible by applying the IPC/NACE concordance scheme developed by Eurostat in 2014[5].

The RCA value of 4.60 indicates India is strongly specialised in pharmaceutical products and preparations. This higher specialisation may be the result of marked rise in the privative R&D in the pharmaceutical sector. As highlighted by Mani (2009), the pharmaceuticals private sector R&D investment in India has been growing at a rate close to 35% per annum. Other areas of specialisation (sectors with RCA >1) include food products and beverages, coke and refined petroleum products, basic chemicals, pesticides and agro-chemicals, man-made fibres and tanks, reservoirs & metal containers. Conversely, some sectors where India exhibits significant weaknesses among others include computer and peripheral equipment, communication equipment, electronic components and boards, consumer electronics, optical instruments, motor vehicles.

In contrast to India, China demonstrates strong specialisation in computers & peripheral equipment, communication equipment, optical instruments & photographic equipment, electric motors, generators, transformers and electricity distribution apparatus, wiring and wiring devices, electrical lighting equipment, other general-purpose machinery, domestic appliances, other electric equipment, and other transport equipment.

[5] This concordance scheme has been developed and validated by matching IPC subclasses to industries via an assessment of a representative sample of firms-owned patents. The exercise has resulted in an allocation of IPC codes to NACE categories.

NACE Classification	India	China	Korea	Japan	US	EU
Food Products	**1.25**	0.88	0.67	0.69	0.99	**2.03**
Beverages	**1.63**	0.49	**1.61**	**1.06**	0.79	**1.12**
Tobacco Products	0.35	**3.59**	0.66	0.46	0.55	0.53
Printing & Service Activities Related to Printing	0.48	0.28	0.60	**1.34**	0.84	**1.16**
Textiles	0.88	0.58	0.86	**1.12**	**1.18**	**1.09**
Wearing Apparel	0.00	0.94	**1.20**	0.67	**1.25**	0.88
Paper & Paper Products	0.56	0.40	0.41	0.56	**1.04**	**1.71**
Leather & Related Products	0.34	0.81	**1.86**	0.29	**1.37**	**1.12**
Wood & Products of Wood and Cork	0.27	0.84	0.52	0.60	0.50	**2.07**
Coke & Refined Petroleum Products	**2.15**	0.55	0.58	0.41	**1.48**	**1.08**
Basic Chemicals, Fertilizers & Nitrogen Compounds	**1.45**	0.54	**1.09**	**1.36**	0.95	**1.06**
Man-Made Fibres	**1.02**	0.68	**1.49**	**1.49**	**1.03**	0.93
Pesticides & Other Agrochemical Products	**1.63**	0.37	0.18	0.45	0.86	0.74
Paints & Varnishes	0.47	0.39	0.79	**1.34**	0.94	**1.13**
Soaps & Detergents, Cleansing & Polishing Preps., Perfumes &Toilet Preps.	0.07	0.03	0.13	0.09	0.17	**1.01**
Other Chemical Products	0.80	0.49	0.67	**1.33**	**1.13**	0.96
Basic Pharma Products & Pharma Preps.	**4.60**	0.81	0.76	0.60	**1.38**	0.90
Rubber & Plastic Products	0.35	0.39	0.62	**1.15**	0.84	**2.38**
Other Non-Metallic Mineral Products	0.68	0.55	0.77	**1.49**	0.92	0.94
Basic Metals	0.63	0.73	**1.23**	**1.90**	0.48	**1.10**
Structural Metals	0.00	0.77	0.85	**1.13**	0.77	**1.33**
Tanks, Reservoirs & Containers of Metals	**1.45**	0.93	0.86	0.51	**1.42**	**1.66**
Steam Generators	0.43	0.61	**1.13**	**1.63**	**1.08**	**2.44**
Weapons and Ammunition	0.62	0.39	0.55	0.10	**1.28**	**1.40**
Other Fabricated Metal Products	0.00	0.49	0.54	0.43	0.57	**1.21**
Cutlery, Tools & General Hardware	0.26	0.78	0.99	0.58	0.64	**1.83**
Electronic Components & Boards	0.23	0.94	**1.18**	**1.80**	0.97	0.36
Computers & Peripheral Equipment	0.83	**1.98**	**1.21**	**1.04**	**1.31**	0.56
Communication Equipment	0.39	**2.53**	**1.87**	0.88	**1.03**	0.88
Consumer Electronics	0.34	0.77	0.39	0.97	**1.34**	**1.08**
Instruments & Appliances of Measuring, Testing & Navigation	0.52	0.72	0.70	0.92	**1.13**	**1.08**
Optical Instruments & Photographic Equipment	0.25	**1.00**	**1.07**	**1.88**	0.90	0.71
Electric Motors, Generators, Transformers and Electricity Dist.	0.63	**1.36**	**1.24**	**1.54**	0.60	**1.12**
Wiring and Wiring Devices	0.00	**1.67**	0.85	**1.43**	0.82	**1.18**
Electrical Lighting Equipment	0.31	**2.57**	**1.14**	**1.54**	0.56	**1.02**

Domestic Appliances	**0.38**	**1.49**	**2.06**	**0.79**	**0.65**	**0.96**
Other Electric Equipment	**0.49**	**1.13**	**0.75**	**1.57**	**0.70**	**1.07**
General Purpose Machinery	**0.65**	**0.74**	**0.63**	**1.05**	**0.75**	**1.56**
Other General-Purpose Machinery	**0.57**	**1.16**	**0.94**	**1.19**	**0.89**	**0.93**
Agricultural & Forestry Machinery	**0.68**	**0.93**	**1.00**	**0.65**	**0.89**	**1.21**
Metal Forming Machinery & Machine Tools	**0.44**	**0.72**	**0.79**	**1.20**	**0.77**	**1.41**
Other Special Purpose Machinery	**0.54**	**0.64**	**0.69**	**0.82**	**1.02**	**1.19**
Motor Vehicles	**0.64**	**0.45**	**0.54**	**1.41**	**0.58**	**1.76**
Other Transport Equipment	**0.89**	**1.17**	**1.07**	**0.60**	**0.77**	**1.44**
Other Manufacturing	**0.51**	**0.81**	**0.95**	**0.88**	**1.01**	**0.62**
Medical & Dental Instruments & Supplies	**0.70**	**0.53**	**0.80**	**0.65**	**1.52**	**0.87**
Furniture	**0.41**	**0.90**	**0.97**	**0.48**	**1.02**	**1.27**
Irradiation, Electro-medical & Electrotherapeutic Equipment	**0.00**	**0.67**	**1.36**	**3.00**	**2.53**	**1.27**
Construction of other civil engineering projects	**0.00**	**0.93**	**0.00**	**0.00**	**0.00**	**3.50**

Table 5: Technology Specialization Index, NACE Classification 1995-2019, PCT (by Applicants)
Source: Author's own calculations based on patent applications filed (PCT applications) under various technology domains by the selected countries at PCT.

Table 6 summarizes the main findings of this section, offering an overview of the major fields of specialization and de-specialization for each country. It is quite important to observe that India appears strongly de-specialised in fast growing technologies such as computer, optics, electronics and communication, while holding a significant advantage in technologies related to pharmaceuticals, coke and petro-products, pesticides and agro-chemicals, basic chemicals and beverages. In contrast, China, Korea, and Japan excel in relatively high-tech areas such as communication equipment, computers, optics, irradiation, electro-medical and electro-therapeutic equipment.

The EU demonstrates strength in traditional technology fields, particularly excelling in sectors such as motor vehicles, general purpose machinery, paper & paper products, food products, and construction etc. Conversely, the EU weakness is concentrated in fields related to electronic components & boards, computers & peripheral equipment, optical instruments & photographic equipment, communication equipment, pharmaceuticals pesticides and agrochemical products etc.

Finally, the US exhibits high levels of specialization in pharmaceuticals, tanks, reservoirs and containers of metals, coke and refined petroleum products, medical and dental instruments, irradiation, electro-medical and electrotherapeutic equipment, arms and ammunition etc. On the other hand, calculated RCA values are consistently lower than one for sectors like construction, soaps and detergents, basic metals, tobacco products, motor vehicles etc., thereby suggesting relative weakness in these sectors for the US.

It is important to observe there is a certain similarity amongst countries in specialisation and de-specialisation patterns. For instance, China and Korea essentially specialise in same technology fields. A glance of the Table 6 reveals that among the top 10 sectors of technological specialisation, China and Korea share at least 4 similar technological areas in which both countries specialise, albeit with varying RCA values. Likewise, specialisation pattern of Korea and Japan also reveal many similar technology areas in which both countries specialise. Additionally, India and the USA both specialise in pharmaceuticals, and coke & petroleum products, but India has a greater RCA in both sectors. Therefore, several common sectors exist where all selected countries specialize or have a comparative advantage, though with varying degrees. Simultaneously, many areas of de-specialization also align across countries.

Table 6: Strong (specialised) and Weak (de-specialised) NACE Sectors of Selected Countries

NACE Sectors	India	China	Korea	Japan	US	EU
Food Products	Strong	Weak	Weak	Weak	Weak	Strong
Beverages	Strong	Weak	Strong	Strong	Weak	Strong
Tobacco Products	Weak	Strong	Weak	Weak	Weak	Weak
Printing & Service Activities Related to Printing	Weak	Weak	Weak	Strong	Strong	Weak
Textiles	Weak	Weak	Weak	Strong	Strong	Strong
Wearing Apparel	Weak	Weak	Strong	Weak	Strong	Weak
Paper & Paper Products	Weak	Weak	Weak	Weak	Strong	Strong
Leather & Related Products	Weak	Weak	Strong	Weak	Strong	Strong
Wood & Products of Wood and Cork	Weak	Weak	Weak	Weak	Strong	Strong
Coke & Refined Petroleum Products	Strong	Weak	Weak	Weak	Strong	Strong
Basic Chemicals, Fertilizers & Nitrogen Compounds	Strong	Weak	Strong	Strong	Strong	Strong
Man-Made Fibres	Strong	Weak	Strong	Strong	Weak	Weak
Pesticides & Other Agrochemical Products	Strong	Weak	Weak	Weak	Weak	Weak
Paints & Varnishes	Weak	Weak	Weak	Strong	Weak	Strong
Soaps & Detergents, Cleansing & Polishing Preps., Perfumes &Toilet Preps.	Weak	Weak	Weak	Strong	Weak	Strong
Other Chemical Products	Weak	Weak	Weak	Strong	Strong	Weak
Basic Pharma Products & Pharma Preps.	Strong	Weak	Weak	Weak	Strong	Weak
Rubber & Plastic Products	Weak	Weak	Weak	Strong	Weak	Strong
Other Non-Metallic Mineral Products	Weak	Weak	Weak	Strong	Weak	Weak
Basic Metals	Weak	Weak	Strong	Strong	Weak	Strong
Structural Metals	Weak	Weak	Weak	Strong	Weak	Strong
Tanks, Reservoirs & Containers of Metals	Strong	Weak	Weak	Weak	Strong	Strong
Steam Generators	Weak	Weak	Strong	Strong	Strong	Strong
Weapons and Ammunition	Weak	Weak	Weak	Weak	Strong	Strong
Other Fabricated Metal Products	Weak	Weak	Weak	Weak	Weak	Strong
Cutlery, Tools & General Hardware	Weak	Weak	Weak	Weak	Weak	Strong
Electronic Components & Boards	Weak	Weak	Weak	Weak	Weak	Weak
Computers & Peripheral Equipment	Weak	Strong	Strong	Strong	Strong	Weak
Communication Equipment	Weak	Strong	Strong	Strong	Strong	Weak
Consumer Electronics	Weak	Weak	Strong	Weak	Strong	Strong
Instruments & Appliances of Measuring, Testing & Navigation	Weak	Weak	Weak	Weak	Strong	Strong
Optical Instruments & Photographic Equipment	Weak	Strong	Strong	Strong	Weak	Weak
Electric Motors, Generators, Transformers and Electricity Dist.	Weak	Strong	Strong	Strong	Weak	Strong
Wiring and Wiring Devices	Weak	Strong	Weak	Strong	Weak	Strong
Electrical Lighting Equipment	Weak	Strong	Strong	Strong	Weak	Strong
Domestic Appliances	Weak	Strong	Strong	Weak	Weak	Weak
Other Electric Equipment	Weak	Strong	Weak	Strong	Weak	Strong
General Purpose Machinery	Weak	Weak	Weak	Strong	Weak	Strong
Other General-Purpose Machinery	Weak	Strong	Weak	Strong	Weak	Weak
Agricultural & Forestry Machinery	Weak	Weak	Strong	Weak	Weak	Strong
Metal Forming Machinery & Machine Tools	Weak	Weak	Weak	Strong	Weak	Strong
Other Special Purpose Machinery	Weak	Weak	Weak	Weak	Strong	Strong
Motor Vehicles	Weak	Weak	Weak	Strong	Weak	Strong
Other Transport Equipment	Weak	Strong	Strong	Weak	Weak	Strong
Other Manufacturing	Weak	Weak	Weak	Weak	Strong	Weak
Medical & Dental Instruments & Supplies	Weak	Weak	Weak	Weak	Strong	Weak
Furniture	Weak	Weak	Weak	Weak	Strong	Strong
Irradiation, Electro-medical & Electrotherapeutic Equipment	Weak	Weak	Weak	Strong	Strong	Strong
Construction of other civil engineering projects	Weak	Weak	Weak	Weak	Weak	Strong

Source: Author's own calculations based on patent applications filed (PCT applications) under various technology domains by the selected countries at PCT.

VII. CONCLUSION

The paper investigates the patent filing trends for India, China, and Korea across various IP systems, exploring their potential catching up in patent volume with triadic economies. Additionally, the paper offers a comprehensive overview of the recent patterns of technological specialization among countries. The study utilizes application data from six different patent systems such as PCT, EPO, USPTO, JPO, CNIPA, and IPO. The analysis of technological specialization for designated countries is based on PCT patent data retrieved from the WIPO database. Specialization patterns are assessed at the NACE industry level using the IPC/NACE concordance scheme, mapping 35 IPC technology fields into 49 NACE industrial sectors to determine sectors of relative comparative advantage and disadvantage.

Assuming that patent data provides relevant information about the direction and intensity of innovation, the study infers that the geography of innovation is changing rapidly worldwide. Throughout much of the second half of the 20th century, the US, Japan and the EU dominated the global patent landscape. However, in recent decades several other countries have been catching up with the most advanced economies. Notably, South Korea is converging fast with the triadic countries. Moreover, since the mid-1980s, both China and, lately, India have been following an apparently similar trajectory of convergence in terms of patent counts at PCT, EPO and USPTO.

In terms of gross patent demand at major national PTOs, China has overtaken South Korea and is likely to soon close the gap with the US and Japan. However, India still faces a significant gap, not only in PCT system but also in other IP systems. The observation of Chinese, Korean and Indian growth trends over the last two decades suggests the catch up with the US at PCT might happen in a period of less than one year for China, less than a decade for Korea and slightly longer (around two and half decades) for India.

In addition to analysing the Chinese and Indian IP systems and the PCT system, the study incorporated data from the European, US and Japanese patent systems. While the patent applications filed by China across each of these IP systems is currently below 10 thousand per year, a simple extrapolation of the patent filings for the last two decades suggest that China could potentially catch up the USA's numbers at EPO within a span of 6 years and at USPTO and JPO in about 2 and 6 years respectively. In the case of India linear extrapolation indicates a possible catch up occurring a few years later than China in most of the systems observed.

The paper raises the crucial question of the sustainability of economic growth in China and India, and their potential convergence with advanced countries in output and income in a relatively short period. The analysed data allows us to infer that as innovation takes centre stage in these two countries, especially in China, it appears that they are assembling the necessary ingredients to compete over the coming decades and propel their GDP and income levels further.

However, this catch-up would primarily be in terms of volume, not per capita intensity. With large populations and growing regional imbalances in both countries, areas like Shanghai, Pearl River Delta, Bangalore, and Mumbai are likely to grow faster, approaching the development levels of advanced economies. These imbalances, arising from innovation dynamics, agglomeration economies and regional specific factors, may impede the integrated development of China's and India's national innovation systems, posing challenges to the diffusion of advanced knowledge across broader economic and social environments.

The conclusions of the study rests on the assumption that patenting activities offer significant insights into innovation patterns. This aligns with vast literature dating back to the 1960s linking patenting and technological innovation. Moreover, within the same analytical scope, there are at least three aspects that merit subsequent investigation following this paper. Firstly, detailed exploration is needed for specialization analysis within IPC and NACE classes at a disaggregated level. Secondly, there is a need to examine the relationship between R&D and new patents, contrasting IPC and sectoral patent productivity in emerging economies with patterns observed in advanced economies. Thirdly, an investigation into the role of foreign firms in China and India regarding domestic patenting, comparing the quality and duration of patents of foreign origin with domestic patents.

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