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On the Obituary of Scientific Knowledge Monopoly

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Abstract

The August 15th 2013 Shanghai Academic Rankings of World Universities (ARWU) should leave policy makers wondering about whether the impressive growth experienced by 'latecomers in the industry' has moved hand-in-hand with contribution to knowledge by means of scientific publications. Against this background, we model the obituary of scientific knowledge monopoly in 99 countries using 21 catch-up panels from 6 regions (South Asia, Europe & Central Asia, East Asia & the Pacific, Middle East & North Africa, Latin America & the Caribbean and, Sub-Saharan Africa). The findings broadly show that the obituary of scientific knowledge monopoly by developed countries is not in the near-horizon. Advanced nations that have mastered the dynamics of knowledge monopoly will continue to lead the course of knowledge economy. Justifications for the patterns and policy implications are discussed.

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1. Introduction

We model tendencies, dynamics and trajectories of scientific publications in 99 countries. Consistent with the underlying regional scope/picture of the Shanghai rankings, the richness of our data enables us to disaggregate the dataset into six fundamental regional characteristics: South Asia, Europe & Central Asia, East Asia & the Pacific, Middle East & North Africa, Latin America & the Caribbean and, Sub-Saharan Africa (SSA). Twenty-one catch-up panels are examined based on the fundamental regional characteristics. For each combination of fundamental characteristics, three issues are examined: the presence or not of catch-up processes, the rates of the catch-up processes and the respective half-lives of shocks.

As nations that have mastered knowledge economy (KE) continue to steer development in the global arena, the relevance of KE in 21st century development is no longer an issue of moderate consensus (Albuquerque, 2000; Esler & Nelson 1998; Jelili & Jellal, 2002; Wolff & Jellal, 2003; Murray & Stern, 2005; Mowery & Sampat 2005; World Bank, 2007; Weber, 2007; Mazzoleni & Nelson, 2007; Amavilah, 2009; Mazzoleni, 2008; Chandra & Yokoyama, 2011; Weber, 2011; Asongu, 2012a,b; Asongu, 2013a,b; Andrés & Asongu, 2013; Andrés et al., 2013). Against this background, the role of universities and public research organizations in facilitating the transition from product-based economies to knowledge-based economies is crucial. As shown by the early experiences of Germany in the 19th century and late experiences of Asian countries (Japan, South Korea, Taiwan, Singapore and China), beside education, universities contribute to a country's development by undertaking basic and applied research.

The phenomenon of catch-up has been referred to as the process via which once backward countries successfully narrow the gap in productivity and income with frontier countries. In essence, the process has been historically associated with the adoption and transfer of existing techniques from mature industries in leading countries to backward ones. As a complex process, catch-up encompasses a plethora of aspects, actors and dimensions of an economic system; among them universities and public research centers have been regarded as central players in past and recent experiences in the catch-up processes (Mazzoleni, 2008). These organizations constitute the supporting infrastructure for the acquisition and building of technological and scientific capabilities by providing the general and specialized training, instrumentation and equipment, scientific and technological information and also contribute to the design of new processes and products (Morrison et al., 2009).

The 2013 Shanghai Academic Rankings of World Universities (ARWU, 2013)[1] present a dominant picture of developed countries vis-à-vis the developing nations. It reflects the dominance of North America, Western Europe, Australia, Japan and China; the catch-up struggle of Latin America and miserable representation of Africa, Eastern Europe & Central Asia, South East Asia and the Middle East[2]. Two facts result: (1) the historic dominance of advanced nations is not unexpected and; (2) the rankings reflect a picture at a given point in time. Accordingly, whereas the rankings reflect a comparative state of knowledge contribution, understanding the dynamics in terms of evolution of and catch-up by previously lagging countries requires a more in-depth analysis of the trends of scientific and technical publications. By trends this note refers to dynamics, trajectories and tendencies of scientific contribution in terms of feasibility of catch-up, rate of catch-up and half-lives of shocks. In essence, policy makers should be curious to know whether the impressive growth experienced

[1] The 2013 ARWU published by the Center for World-Class Universities at Shanghai Jiao Tong University that started about 10 years ago has been presenting the world Top 500 universities annually from a transparent methodology and reliable data. In addition the Shanghai ARWU is considered as the most trustworthy and precursor of global university rankings.

[2] Please see http://www.shanghairanking.com/.

by latecomers in the industry has moved hand-in-hand with contribution to knowledge by means of scientific publications.

It is logical to expect catch-up in contribution to knowledge by means of scientific publications for a multitude of reasons. The availability of skilled teachers and workers, the migration of technicians from leading countries and the training of students abroad are crucial in enabling conditions for building-up indigenous technological capabilities (Kim & Nelson, 2000; Mowery & Sampat, 2005; Morrison et al., 2009). In line with Morrison et al. (2009), what matters today in the catch-up processes is that basic and applied research represent along with other ingredients a key determinant for building scientific capabilities which are inputs for innovation and growth (Morrison et al., 2009; Balconi et al., 2010). Since this assertion is true today in the context of developing countries more than ever, Mazzoleni & Nelson (2007) have advanced two reasons to substantiate this claim: (1) the changing nature of technology and science (D'Este & Patel, 2007) and; (2) the impact of globalization on the diffusion of knowledge and the relative importance of scientific actors.

In light of the above, the present note has a twofold contribution to the catch-up literature: filling a missing gap in the literature and providing an in-depth picture of the Shanghai rankings. Firstly, as far as we have reviewed, while comparative literature on scientific and research productivity of advanced nations has flourished in recent years showing how varying contexts and strategies enable countries to reduce the gap of frontier countries, little is known about how and whether cross-country gaps in scientific productivity are expanding or narrowing. This note intends to contribute to the latter stream by understanding if the impressive growth experienced by latecomers in the industry has been translated into a similar catch-up in contribution to knowledge by means of scientific publications. Secondly, while the August 15th 2013 publication of Shanghai rankings shows a very bleak picture of regional disparities, the painting is not dynamic in providing details about trends in scientific and technical publications. In essence, the ranking does not answer the following questions. (1) Are regions with initially low levels of publication catching-up frontier countries? (2) If so what are the rates of catch-ups and half-lives of shocks? The present note addresses the issues. The rest of the note is organized as follows. Section 2 discusses the data and the methodology. The empirical analysis is covered in Section 3. Section 4 concludes.

2. Data and Methodology

2.1 Data

We assess a sample of 99 countries with data from the World Bank Development Indicators (WDI), the World Intellectual Property Organization (WIPO) and the Global Market Information Database (GMID) for the period 1994-2010. The limitations to a 17 year annual periodicity and 99 countries are due to constraints in data availability on scientific publications. Accordingly, the dependent variable is the number of scientific and technical journal articles published annually.

2.1.1 Determination of fundamental characteristics and catch-up panels

In line with Asongu (2012a), it is unlikely to find catch-up processes within a heterogeneous set of countries. Accordingly, recent studies have stressed the relevance of a variety of contexts (Mazzoleni, 2008; Mazzoleni & Nelson, 2007) and geographical areas (Morrison et al., 2009) in the catch-up process. In essence, the determination of fundamental characteristics should be based on factors that naturally determine scientific and technical publications such as research and development budgets, degree of IPRs protections, rate of higher education…etc. However, as it has been cautioned in recent catch-up studies (Asongu, 2012a), macroeconomic fundamental characteristics have the draw-back of being time-dynamic. Therefore, the same threshold may not be consistent over time, especially in a horizon of 17 years. In accordance with recent catch-up literature (Narayan et al., 2011; Asongu, 2012a), we shall take a minimalistic approach in the determination of fundamental characteristics and control for fundamental determinants of scientific publications in the estimations. The main fundamental characteristic criterion adopted in the study is 'regional proximity' due to the picture presented by the Shanghai rankings.

In fact regional proximity is fundamental in the catch-up process because Morrison et al. (2009) have postulated that differences over time and across geographical areas also explain the catch-up process. More so, the inclusion of these regions is broadly consistent with the empirical underpinnings of the catch-up literature (Narayan et al., 2011; Asongu, 2013c; Andrés & Asongu, 2013). The regions include: South Asia, Europe & Central Asia, East Asia & the Pacific, Middle East & North Africa, Sub-Saharan Africa and, Latin America & the Caribbean. From the 6 fundamental regional characteristics, 21 catch-up panels on which the empirical analysis will be based are derived (South Asia, South Asia and Europe & Central Asia, South Asia and East Asia & the Pacific, South Asia and Middle East & North Africa, South Asia and Latin America & the Caribbean, South Asia and Sub-Saharan Africa, Europe & Central Asia, Europe & Central Asia and East Asia & the Pacific, Europe & Central Asia and Middle East & North Africa, Europe & Central Asia and Latin America & the Caribbean, Europe & Central Asia and Sub-Saharan Africa, East Asia & the Pacific, East Asia & the Pacific and Middle East & North Africa, East Asia & the Pacific and Latin America & the Caribbean, East Asia & the Pacific and Sub-Saharan Africa, Middle East & North Africa, Middle East & North Africa and Latin America & the Caribbean, Middle East & North Africa and Sub-Saharan Africa, Latin America & the Caribbean, Latin America & the Caribbean and Sub-Saharan Africa and, Sub-Saharan Africa).

2.1.2 Choice of control variables

The choice of control variables is in accordance with the theoretical underpinnings of conditional catch-up which state that, if countries differ in characteristics that determined scientific and technical publications, it is possible for conditional catch-up to take place. Therefore, we control for such factors that determine publications which include: research and development (R&D) expenditure[3], tertiary school enrolment, internet penetration[4] and protection of Intellectual Property Rights (IPRs) in terms of Main IPRs law and WIPO[5] Treaties. Consistent with Murray & Stern (2005), the potential for IPRs to stimulate the diffusion of scientific knowledge is at the core of several contemporary issues: a central agenda is how IPRs over a given piece of knowledge affects the ability of future researchers to construct upon that knowledge in their own scientific research endeavours. From intuition, tertiary school enrolment, R&D expenditure and the degree of internet penetration naturally facilitate scientific activities. These control variables are broadly in line with the determinants of knowledge production recently documented by Amavilah (2009).

Information about the summary statistics (with presentation of countries), correlation analysis (showing the basic correlations between key variables employed in the study) and variable definitions (with corresponding data sources) are presented in Appendix 1, Appendix

[3] It should be noted that, while R&D/GDP may not be a cyclical variable, its usage for conditional convergence is because, consistent with the convergence theory, conditional convergence is likely to occur if there are cross-country differences in factors that determine scientific publication. Accordingly, R&D/GDP is a factor that determines scientific publication.

[4] In accordance with Esler & Nelson (2009), the growing cost of traditional scientific scholarly communication coupled with the soaring of widely available internet communication tools such as the World Wide Web (www) have provided a catalyst for a revolution in the exchange of scientific and technical information.

[5] World Intellectual Property Organization.

2 and Appendix 3 respectively. The descriptive statistics of the variables show that, there is quite some degree of variation in the data utilized so that one should be comfortable and confident that reasonable estimated nexuses would emerge. The purpose of the correlation matrix is to mitigate issue of multicolinearity and overparametization. From the correlation coefficients, we do not find any major issues in terms of the relationships to be estimated.

2.2 Methodology

The estimation strategy is typically in line with modeling the future of KE by Asongu (2013a). Consistent with recent literature (Asongu, 2012a, 2013a; Andrés & Asongu, 2013), the estimation approach is based on β-convergence due to constraints in the data set.

In line with the convergence literature (Fung, 2009, p. 59; Asongu, 2012a), the equation below is the standard approach for investigating conditional convergence if $W_{i,t}$ is taken as strictly exogenous.

$$\ln(Y_{i,t}) = \rho \ln(Y_{i,t-\tau}) + \delta W_{i,t-\tau} + \eta_i + \xi_t + \varepsilon_{i,t} \qquad (1)$$

Where $Y_{i,t}$ is the proxy for the rate of scientific and technical publications in country *i* at period *t*. $W_{i,t}$ is a vector of determinants of the publications, η_i is a country-specific effect, ξ_t is a time-specific constant and $\varepsilon_{i,t}$ an error term. According to Fung (2009, p. 59) and recent catch-up literature (Asongu, 2012a, 2013a; Andrés & Asongu, 2013), if the lagged variable is in a unit cycle ($0 < |\rho| < 1$) in Eq. (1), then $Y_{i,t}$ is dynamically stable around the path with a trend of publication rate the same as that of W_t, and with a height relative to the level of W_t. The variables incorporated in $W_{i,t-\tau}$ and the individual effect η_i are measures of the long-run level the publications market is converging to. Therefore, the country-specific effect η_i emphasizes other determinants of a country's steady state not captured by $W_{i,t-\tau}$.

The conditions outlined above for catch-up are valid if and only if, $W_{i,t}$ exhibits strict exogeneity. Unfortunately, this is not realistic because, while R&D, internet penetration, tertiary school enrolment and IPR laws (components of $W_{i,t}$) have an incidence on the rate of scientific publication, the reverse effect cannot be ruled-out. Therefore, we are confronted with the issue of endogeneity in which control variables ($W_{i,t}$) are correlated with the error term ($\varepsilon_{i,t}$). In addition, country- and time-specific effects could be correlated with other variables in the model, which is very likely when lagged endogenous variables are included in the equations. A strategy employed to tackle the problem of the correlation between the individual specific-effect and the lagged dependent variables consists of eliminating the individual effect by first differencing. Thus Eq. (1) becomes:

$$\ln(Y_{i,t}) - \ln(Y_{i,t-\tau}) = \rho(\ln(Y_{i,t-\tau}) - \ln(Y_{i,t-2\tau})) + \delta(W_{i,t-\tau} - W_{i,t-2\tau}) + (\xi_t - \xi_{t-\tau}) + (\varepsilon_{i,t} - \varepsilon_{i,t-\tau}) \qquad (2)$$

Accordingly, Eq. (2) still presents another concern; estimates by Ordinary Least Square (OLS) are biased because there remains a correlation between the lagged endogenous independent variable and the error term. To address the issue, we estimate the regression in differences jointly with the regression in levels using the Generalized Method of Moments (GMM) estimation. Arellano & Bond (1991) has suggested an application of the GMM that takes account of all the orthogonality conditions between the lagged dependent variables and the error term. The process employs lagged levels of the regressors as instruments in the difference equation, and lagged differences of the regressors as instruments in the level equation, hence exploiting all the orthogonality conditions between the lagged dependent variables and the error term. In accordance with Bond et al. (2001, pp. 3-4), we prefer the system GMM estimator (Arellano & Bover, 1995; Blundell & Bond, 1998) relative to the difference GMM estimator (Arellano & Bond, 1991).

The GMM estimation strategy has been substantially applied in catch-up studies. In specifying the model, we choose the *two-step* GMM because it corrects the residuals for heteroscedasticity[6]. The hypothesis of no auto-correlation in the residuals is an important consideration as lagged variables are to be used as instruments for the dependent variables. In essence, the estimation depends on the assumption that the lagged values of the dependent variable and other independent variables are valid instruments in the regression. The validity of the instruments is assessed with the Sargan over-identifying restrictions (OIR) test.

According to Islam (1995, p. 1141), yearly time spans are too short to be appropriate for studying catch-up processes, as short-run (business cycle) disturbances may loom substantially in such brief periods. Therefore, considering the data span of 17 years, we are consistent with Asongu (2012a) and recent KE literature (Asongu, 2013a) in using two-year non-overlapping intervals (NOI)[7]. This means in our analysis, τ is set to 2[8]. We also measure the persistence by calculating the half-lives of publication deviations. That is, the amount of time it takes a shock to a series to revert half-way back to its mean value. The approximate half-life of a shock to $Y_{i,t}$ is computed as $-\ln(2)/\ln(\rho_i)$, where $\beta_i \equiv \rho_i - 1$. Whereas the persistence parameter (ρ_i) captures the spread of publication convergence within and across regions, our primary focus is on β_i: the coefficients on the lagged log of scientific publications ($Y_{i,t}$). Accordingly, the nearer β_i is to zero, the longer is the estimated half-life of a shock (Ralhan & Dayanandan, 2005).

3. Empirical analysis

3.1 Presentation of results

This section examines three main issues underpinning the motivation of the study: (1) assessment of cross-regional catch-up processes; (2) computation of the catch-up rates and; (3) determination of the half-lives of shocks. While only the information criteria and summary of the findings are presented in Table 1 and Table 2 respectively due to space constraints, full results leading to the summary can be provided upon request. In the summary, the three issues are addressed. The findings are also presented in terms of absolute (unconditional) and conditional catch-up processes.

While, unconditional (absolute) catch-up is estimated with just the lagged difference of the endogenous variable as independent variable, conditional catch-up is in the presence of

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[6] In the *one-step* approach, the residuals are considered to be homoscedastic.

[7] There are 9 two-year non-overlapping intervals: 1994; 1995-1996; 1997-1998; 1999-2000; 2001-2002; 2003-2004; 2005-2006; 2007-2008; 2009-2010. Due to data and periodical constraints, the first interval is short of one year.

[8] Borrowing from Asongu (2013a), beside the two justifications provided above, we may cite three additional bases for the two-year NOI. (1) NOI with a higher numerical value (say three-year NOI) absorbs more short-run disturbances at the cost of weakening the model. Hence the preference for the two-year NOI over the three/four/five-year NOI is further justified by the need to exploit the time series dimensions as much as possible. (2) A corollary to the above point is the positive side of additional degrees of freedom necessary for conditional convergence modeling. Thus, given the time span of 17 years, a higher order of NOI will greatly limit conditional convergence analysis. (3) Heuristically from a visual analysis, the rate of scientific publications does not show evidence of persistent business cycles (short-term) disturbances that require higher NOI.

control variables. In order to examine the validity of the model and indeed the catch-up hypothesis, we perform two tests, notably: the Sargan-test which assesses the over-identification restrictions and; the Arellano and Bond test for autocorrelation which examines the null hypothesis of no autocorrelation. The Sargan-test examines if the instruments are uncorrelated with the error term in the equation of interest. The Sargan null hypothesis is the position that the instruments as a group are strictly exogenous (do not suffer from endogeneity), which is needed for the validity of the GMM estimates. But for a few exceptions, we notice that the Sargan-test statisitics often appear with a p-value greater than 0.10. Hence, its null hypothesis is not rejected for the most part. We also conduct the second order autocorrelation test and notice that for an overwhelming majority of estimated models, we are unable to reject the null hypothesis for the absence of autocorrelation. While 'not specifically applicable' (nsa) is used where we are unable to model due to issues in degrees of freedom, 'not applicable' (na) is employed in situations of insignificant evidence of catch-up.

Table 1 shows the information criteria on which the summary of the findings in Table 2 is based. The information criteria have already been covered above: lagged endogenous variable plus second order autocorrelation, Sargan OIR and Wald tests. In the summary of the findings in Table 2, AC, CC, Rate of C represent Absolute Catch-up, Conditional Catch-up, and rate of Catch-up respectively. We also report Beta from which the rate of catch-up is computed.

The following conclusions could be drawn from the summary. (1) There is evidence of AC among countries of the same region (Latin American & the Caribbean (LAC), South Asia, SSA) and between countries of different regions (South Asia and LAC, LAC & SSA); CC between South Asia and Europe & Central Asia on the one hand and, between the latter and all other regions. (2) The overwhelming absence of cross-regional catch-ups demonstrates that the obituary of scientific knowledge monopoly remains an illusion. (3) The convergence rate varies from 1% per annum (p.a.) to 4% p.a. with corresponding estimated half-lives of 69 years (yrs) and 17 yrs respectively. Hence, the lower the rate of convergence, the more time it takes for countries within or across regions to converge to a steady state equilibrium (measured in half-life). It should also be noted that, the speed of convergence increases and corresponding years to full convergence decreases when the NOI is set at 1. But setting the NOI at 1 does not change the overall nature of the results which is a general absence of catch-up patterns.

3.2 Discussion of results and policy implications

It is relevant to understand the economic intuition motivating absolute and conditional catch-ups before we dive into the discussion of results. Based on the picture of the Shanghai rankings underpinning the analysis, absolute catch-up in scientific publications takes place when countries share similar fundamental characteristics with regard to factors governing scientific publications such that, only variations across countries in initial levels of publications exist. Absolute catch-up therefore results from factors such as regional proximity, since cross-regional differences determine scientific activity (Morrison et al., 2009); among others. Absolute catch-up also occurs because of adjustments common to the regional fundamental characteristics of publications. Therefore, based on intuition, variations in initial conditions may significantly affect the absolute catch-up processes due to the following. (1) The start of the catch-up process has a precondition: certain levels of scientific internal development which may significantly differ across countries within the same homogenous panel. (2) Countries within the same region may allocate significantly different levels of budget to scientific activities. Hence, the overwhelming absence of absolute catch-up in the findings is traceable to some of the above factors.

Table 1: Information criteria

		Regions											
		South Asia		ECA		EAP		MENA		LAC		SSA	
		AC	CC	AC	CC	AC	CC	AC	CC	AC	CC	AC	CC
South Asia (SA)	Initial	0.973*** (0.000)	nsa	---	---	---	---	---	---	---	---	---	---
	AR(2)	0.186 (0.852)	nsa	---	---	---	---	---	---	---	---	---	---
	OIR	1.865 (1.000)	nsa	---	---	---	---	---	---	---	---	---	---
	Wald	16.73*** (0.000)	nsa	---	---	---	---	---	---	---	---	---	---
Europe & CA	Initial	1.02*** (0.000)	0.96*** (0.000)	1.02*** (0.000)	0.97*** (0.000)	---	---	---	---	---	---	---	---
	AR(2)	0.722 (0.470)	-0.563 (0.573)	0.720 (0.471)	-0.624 (0.532)	---	---	---	---	---	---	---	---
	OIR	42.090 (0.160)	31.745 (0.201)	40.148 (0.216)	29.152 (0.304)	---	---	---	---	---	---	---	---
	Wald	3054*** (0.000)	14678*** (0.000)	27747*** (0.000)	17657*** (0.000)	---	---	---	---	---	---	---	---
East Asia & the P	Initial	1.02*** (0.000)	1.310* (0.080)	1.02*** (0.000)	0.97*** (0.000)	1.024*** (0.000)	1.214*** (0.000)	---	---	---	---	---	---
	AR(2)	1.141 (0.253)	0.050 (0.959)	0.803 (0.421)	-0.675 (0.499)	1.120 (0.262)	-0.768 (0.442)	---	---	---	---	---	---
	OIR	11.472 (0.999)	8.254 (0.999)	45.448* (0.090)	33.941 (0.136)	9.798 (1.000)	5.718 (0.999)	---	---	---	---	---	---
	Wald	2775*** (0.000)	432.9*** (0.000)	51887*** (0.000)	19742*** (0.000)	35277*** (0.000)	441.25*** (0.000)	---	---	---	---	---	---
MENA	Initial	1.030*** (0.000)	1.073*** (0.000)	1.02*** (0.000)	0.97*** (0.000)	1.026*** (0.000)	1.041*** (0.000)	1.032*** (0.000)	-0.032 (0.984)	---	---	---	---
	AR(2)	0.798 (0.424)	-0.551 (0.581)	0.965 (0.334)	-0.763 (0.445)	0.986 (0.323)	-0.752 (0.451)	0.795 (0.426)	-0.092 (0.926)	---	---	---	---
	OIR	14.902 (0.998)	5.524 (1.000)	47.836* (0.058)	32.869 (0.165)	22.996 (0.923)	11.777 (0.992)	12.337 (0.999)	0.000 (1.000)	---	---	---	---
	Wald	1735*** (0.000)	3872*** (0.000)	33704*** (0.000)	7057*** (0.000)	103991*** (0.000)	3180*** (0.000)	15072*** (0.000)	3252*** (0.000)	---	---	---	---
LAC	Initial	0.99*** (0.000)	1.05*** (0.000)	1.00*** (0.000)	0.99*** (0.000)	1.004*** (0.000)	1.094*** (0.000)	1.003*** (0.000)	1.086*** (0.000)	0.984*** (0.000)	1.086*** (0.000)	---	---
	AR(2)	-0.835 (0.403)	-0.982 (0.326)	-0.403 (0.686)	-0.934 (0.350)	-0.794 (0.427)	-1.265 (0.205)	-0.654 (0.512)	-0.967 (0.333)	-0.836 (0.402)	-1.231 (0.218)	---	---
	OIR	19.999 (0.973)	9.969 (0.998)	51.69** (0.026)	37.92* (0.061)	27.787 (0.765)	18.67 (0.850)	30.822 (0.624)	17.675 (0.887)	17.982 (0.989)	7.595 (0.999)	---	---
	Wald	2116*** (0.000)	5691*** (0.000)	10407*** (0.000)	10520*** (0.000)	7175*** (0.000)	4759*** (0.000)	5135*** (0.000)	6348*** (0.000)	1579*** (0.000)	1434*** (0.000)	---	---
SSA	Initial	1.00*** (0.000)	nsa	1.01*** (0.000)	0.978*** (0.000)	1.020*** (0.000)	1.024*** (0.000)	1.021*** (0.000)	0.350 (0.252)	0.982*** (0.000)	1.058*** (0.000)	0.981*** (0.000)	nsa
	AR(2)	-0.182 (0.855)	nsa	0.332 (0.739)	-1.179 (0.238)	-0.114 (0.909)	-1.010 (0.312)	0.086 (0.931)	-0.157 (0.874)	-0.808 (0.418)	-1.199 (0.230)	-0.173 (0.861)	nsa
	OIR	9.740 (1.000)	nsa	45.27* (0.093)	28.833 (0.318)	17.596 (0.990)	9.945 (0.998)	20.472 (0.967)	0.368 (1.000)	25.923 (0.838)	10.421 (0.997)	7.964 (1.000)	nsa
	Wald	1059*** (0.000)	nsa	23077*** (0.000)	20742*** (0.000)	47575*** (0.000)	5727*** (0.000)	30772*** (0.000)	8674*** (0.000)	1819*** (0.000)	3247*** (0.000)	35.343*** (0.000)	nsa

***,**,*: significance levels of 1%, 5% and 10% respectively. P-values in brackets. AR(2): Second Order Autocorrelation test. OIR: Sargan Overidentifying Restrictions test. Initial: lagged endogenous estimated coefficient. ECA: Europe and Central Asia. EAP: East Asia and the Pacific. MENA: Middle East and North Africa. SSA: Sub-Saharan Africa. LAC: Latin America and the Caribbean. The significance of bold values is twofold. 1) The significance of estimated coefficients and the Wald statistics. 2) The failure to reject the null hypotheses of: a) no autocorrelation in the AR(2) tests and; b) the validity of the instruments in the Sargan OIR test. nsa: no catch-up estimation due to issues in degrees of freedom.

Table 2: Summary of catch-up processes based on regions

		Regions											
		South Asia		ECA		EAP		MENA		LAC		SSA	
		AC	CC	AC	CC	AC	CC	AC	CC	AC	CC	AC	CC
South Asia (SA)	Catch-up	Yes	nsa	---	---	---	---	---	---	---	---	---	---
	Initial-1(Beta)	-0.027	nsa	---	---	---	---	---	---	---	---	---	---
	Rate of C	2.7%	nsa	---	---	---	---	---	---	---	---	---	---
	Half-life	25 Yrs	nsa	---	---	---	---	---	---	---	---	---	---
Europe & CA	Catch-up	No	Yes	No	Yes	---	---	---	---	---	---	---	---
	Initial-1(Beta)	na	-0.04	na	-0.03	---	---	---	---	---	---	---	---
	Rate of C	na	4%	na	3%	---	---	---	---	---	---	---	---
	Half-life	na	17 Yrs	na	23 Yrs	---	---	---	---	---	---	---	---
East Asia & the P	Catch-up	No	No	No	Yes	No	No	---	---	---	---	---	---
	Initial-1(Beta)	na	na	na	-0.03	na	na	---	---	---	---	---	---
	Rate of C	na	na	na	3%	na	na	---	---	---	---	---	---
	Half-life	na	na	na	23 Yrs	na	na	---	---	---	---	---	---
MENA	Catch-up	No	No	No	Yes	No	No	No	No	---	---	---	---
	Initial-1(Beta)	na	na	na	-0.03	na	na	na	na	---	---	---	---
	Rate of C	na	na	na	3%	na	na	na	na	---	---	---	---
	Half-life	na	na	na	23 Yrs	na	na	na	na	---	---	---	---
LAC	Catch-up	Yes	No	No	Yes	No	No	No	No	Yes	No	---	---
	Initial-1(Beta)	-0.01	na	na	-0.01	na	na	na	na	-0.016	na	---	---
	Rate of C	1%	na	na	1%	na	na	na	na	1.6%	na	---	---
	Half-life	69 Yrs	na	na	69 Yrs	na	na	na	na	43 Yrs	na	---	---
SSA	Catch-up	No	nsa	No	Yes	No	No	No	No	Yes	No	Yes	nsa
	Initial-1(Beta)	na	nsa	na	-0.03	na	na	na	na	-0.018	na	-0.019	nsa
	Rate of C	na	nsa	na	3%	na	na	na	na	1.8%	na	1.9%	nsa
	Half-life	na	nsa	na	23 Yrs	na	na	na	na	38 Yrs	na	36 Yrs	nsa

C: Catch-up AC: Absolute Catch-up. CC: Conditional Catch-up. Yrs: Years. Initial: estimated lagged endogenous variable. Half-life is in years (yrs). ECA: Europe and Central Asia. EAP: East Asia and the Pacific. MENA: Middle East and North Africa. SSA: Sub-Saharan Africa. LAC: Latin America and the Caribbean. na: not applicable because of absence of significance catch-ups. nsa: no catch-up estimation due to issues in degrees of freedom. Yes: the lagged endogenous variable is statistically significant and in a unit cycle.

Conversely, conditional catch-up is that which is contingent on structural characteristics that determine scientific publications. It shows the type of catch-up whereby, one's own long-term steady state (equilibrium) depends on structural characteristics of the economy. Therefore, within a fundamental characteristic (say South Asia), cross-country differences in factors that explain scientific publications could facilitate conditional convergence. To this effect, the modeling of conditional catch-up has been contingent on characteristics that determined scientific publications, notably: R&D expenditure, internet penetration, tertiary school enrolment and, IPRs laws. Hence, the findings are contingent on the variables we choose and empirically test. Unfortunately, due to issues (constraints) in degrees of freedom, we have not been able to employ more than five components of the conditional information set in modeling the fundamental characteristics. Based on the literature this issue is not major because, some models are not conditioned beyond two macroeconomic control variables (Bruno et al., 2012).

Whereas, we have already covered some potential reasons for the absence of AC in the first paragraph of this section, it is also worthwhile to discuss the findings with regard to the traditional catch-up processes in per capita income. The mission of science in the periphery may not perfectly fit the classical catch-up in per capita because the interplay between science and technology at the periphery shows that from the start of the catch-up process, there is need for investment in scientific infrastructure. Thus, as a focusing device, it is important for scientific infrastructure to spot and explore avenues of technological development that are feasible to a given country, based on national and international conditions. This explanation derives from 'blind research' that may be a waste in less developed countries with huge resource scarcity. This position is in line with Albuquerque (2000) who strongly advocates that given the scarce resources for scientific activities, catch-up countries might concentrate their scientific developments in key disciplines, especially in scientific fields that are sources of industrial development and that have high impact upon industrial firms. Consequently, the distribution of scientific activities before and during catch-up processes might be more concentrated than in other stages of development, with some stages not necessarily compatible with mainstream scientific publications for their relevance.

Four main policy implications result: encouraging indigenous scientific research; fighting brain drain, supporting regional research (and innovation) and improving communication between experts (and policymakers). First, despite the consensus that local-focused research is necessary for the building of national absorptive capacity and supporting of indigenous capabilities, it is also worthwhile to require that the locally tailored research be of publishable scientific standard. This will ease the catch-up process and at the same time the checks on the scientific rigor by external peer-reviewers would validate the soundness of locally-focused policy implications motivating the research. In the same light, incentives should be provided to researchers in less developed countries to be more involved in the contribution to scientific knowledge, especially in areas directly targeting the development of these countries. Second, on the issue of brain drain, if observations on publications used in this paper were based on authors' region/country/continent of origin, the dynamics of the results might have changed in favor of catch-up evidences. In essence, most scientists are fleeing developing countries in search for greener pastures and better working conditions abroad. A great chunk of students from poor countries trained abroad in levels (and areas) that lead to scientific publications never return after obtaining their diplomas. Therefore, measures from source nations, recipient countries, as well as regional and international initiatives are necessary to stem the tide. Third, the support for regional research and innovation is crucial because based on the findings the absence of absolute catch-up means that with the same fundamental characteristic, factors enabling countries with lower levels of publications to catch-up with their counterparts of higher levels are dissimilar. As a policy implication, there should be *encouragement and validation activities targeting local and regional initiatives to promote development of new innovating businesses and 'transfer and exchange' of best practices as well as the establishment of an environment more conducive to innovation*. Such initiatives could preferably be focused on: trans-regional cooperation to facilitate the development of research and innovation; strategies and initiation of programs involving local actors and corresponding activities should be developed in close coordination with inclusive regional policies and; particular attention should be placed on the participation of sampled countries' regions, notably in relation to the transfer of schemes that have been successful at local and national levels. Fourth, common to all three policy strands above is the need for improving communication between experts and policy markers by supporting the establishment of joint work and communication platforms between them at regional levels. And above all, to avoid under documentation of publications, there is need for clear statistical indicators: able to describe the structure, characteristics and performance of 'knowledge-based economies' should be developed at national and regional levels.

4. Conclusion

The August 15th 2013 Shanghai Academic Rankings of World Universities (ARWU) should leave policy makers wondering about whether the impressive growth experienced by 'latecomers in the industry' has moved hand-in-hand with contribution to knowledge by means of scientific publications. Against this background, we model the obituary of scientific knowledge monopoly in 99 countries using 21 catch-up panels from 6 regions (South Asia, Europe & Central Asia, East Asia & the Pacific, Middle East & North Africa, Latin America & the Caribbean and, Sub-Saharan Africa). The findings broadly show that the obituary of scientific knowledge monopoly by developed countries is not in the near-horizon. Advanced nations that have mastered the dynamics of knowledge monopoly will continue to lead the course of knowledge economy. Justifications for the patterns and policy implications are discussed.

Appendices

Appendix 1: Summary statistics and presentation of countries

Panel A: Summary statistics

	Variables	**Mean**	**S.D**	**Min.**	**Max.**	**Obs**
Dependent Variable	Scientific and Technical Journal Articles (STJA)	6.312	2.471	-0.051	12.261	851
Control Variables	Research & Development (R & D)	1.050	0.955	0.000	4.811	481
	Internet Penetration	20.409	24.219	0.000	93.887	840
	Tertiary School Enrolment (TSE)	37.879	21.798	0.000	94.577	703
	Main Intellectual Property Rights Law (Main IPL)	2.081	2.518	0.000	20.000	882
	WIPO Treaties (WIPO T)	3.396	1.849	0.000	7.000	882
Fundamental Characteristics	High Income (HI)	0.438	0.496	0.000	1.000	882
	Upper Middle Income (UMI)	0.295	0.456	0.000	1.000	882
	Lower Middle Income (LMI)	0.243	0.429	0.000	1.000	882
	Low Income (LI)	0.020	0.141	0.000	1.000	882
	English Common Law (English)	0.275	0.447	0.000	1.000	882
	French Civil Law (French)	0.509	0.500	0.000	1.000	882
	German Civil Law (German)	0.173	0.378	0.000	1.000	882
	Scandinavian Civil Law (Scandi)	0.040	0.197	0.000	1.000	882
	South Asia (SA)	0.030	0.172	0.000	1.000	882
	Europe and Central Asia (ECA)	0.438	0.496	0.000	1.000	882
	East Asia and the Pacific (EAP)	0.102	0.302	0.000	1.000	882
	Middle East and North Africa (MENA)	0.132	0.339	0.000	1.000	882
	Sub-Saharan Africa (SSA)	0.081	0.273	0.000	1.000	882
	Latin America and the Caribbean (LAC)	0.192	0.394	0.000	1.000	882

Panel B: Presentation of countries

Albania, Algeria, Argentina, Armenia, Australia, Austria, Azerbaijan, Bahrain, Belgium, Bolivia, Bosnia, Botswana, Brazil, Bulgaria, Cameroon, Canada, Chile, China, Colombia, Costa Rica, Croatia, Cyprus, Czech Republic, Denmark, Dominican Republic, Ecuador, Egypt, El Salvador, Estonia, Finland, France, Germany, Greece, Guatemala, Honduras, Hong Kong, Hungary, Iceland, India, Indonesia, Ireland, Israel, Italy, Japan, Jordan, Kazakhstan, Kenya, Kuwait, Latvia, Lebanon, Lithuania, Luxembourg, Macedonia, Malaysia, Malta, Mauritius, Mexico, Moldova, Montenegro, Morocco, Netherlands, New Zealand, Nicaragua, Nigeria, Norway, Oman, Pakistan, Panama, Paraguay, Peru, Philippines, Poland, Portugal, Puerto Rico, Qatar, Romania, Russia, Saudi Arabia, Senegal, Serbia, Singapore, Slovakia, Slovenia, South Africa, South Korea, Spain, Sweden, Switzerland, Thailand, Tunisia, Turkey, Ukraine, UAE, United Kingdom, United States, Uruguay, Venezuela, Vietnam, Zambia.

S.D: Standard Deviation. Min: Minimum. Max: Maximum. ICT: Information and Communication Technology. Scandi: Scandinavian. Obs: Observations. WIPO: World Intellectual Property Organization.

Appendix 2: Correlation analysis

R& D	Internet	TSE	Main IPL	WIPO T.	STJA	
1.000	0.436	0.566	0.200	0.068	0.631	R&D
	1.000	0.506	0.351	0.335	0.631	Internet
		1.000	0.394	0.355	0.576	TSE
			1.000	0.328	0.349	Main IPL
				1.000	0.181	WIPO T.
					1.000	STJA

R&D: Research & Development. Internet: Internet Penetration. TSE: Tertiary School Enrolment. Main IPL: Main Intellectual Property Law. WIPO T. World Intellectual Property Organization Treaties. STJA: Scientific and Technical Journal Articles.

Appendix 3: Variable definitions

Variables	Signs	Variable definitions (Measurement)	Sources
Journal Articles	STJA	Logarithm of number of Scientific and Technical Journal Articles	World Bank (WDI)
Research and Development	R & D	Research and Development Expenditure (% of GDP)	World Bank (WDI)
Internet Penetration	Internet	Logarithm of Internet Users per 1000	GMID
Literacy	TSE	Tertiary School Enrolment (% of Gross)	GMID
IPRs Law	Main IPL	Main Intellectual Property Law	WIPO
WIPO Treaties	WIIPO T	World Intellectual Property Organization	WIPO

WDI: World Bank Development Indicators. GMID: Global Market Information Database.. Log: Logarithm. WIPO: World Intellectual Property Organization. IPRs: Intellectual Property Rights.

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