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ASIAN TIGER IN NANOTECHNOLOGIES: EVOLUTIONARY PATH OF SCIENTIFICS PRODUCTIONS OF PEOPLE'S REPUBLIC OF CHINA, JAPAN AND SOUTH KOREA

Finardi Ugo

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Direttore Responsabile
Secondo Rolfo

Direzione e Redazione
Cnr-Ceris
Via Real Collegio, 30
10024 Moncalieri (Torino), Italy
Tel. +39 011 6824.911
Fax +39 011 6824.966
segreteria@ceris.cnr.it
http://www.ceris.cnr.it

Sede di Roma
Via dei Taurini, 19
00185 Roma, Italy
Tel. +39 06 49937810
Fax +39 06 49937884

Sede di Milano
Via Bassini, 15
20121 Milano, Italy
tel. +39 02 23699501
Fax +39 02 23699530

Segreteria di redazione
Maria Zittino
m.zittino@ceris.cnr.it

Enrico Viarisio
e.viarisio@ceris.cnr.it

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Asian tigers in nanotechnologies: evolutionary path of scientific production of People's Republic of China, Japan and South Korea

Finardi Ugo*
(*Turin University and National Research Council, Ceris-Cnr)*

Università di Torino - Dipartimento di Chimica I.F.M.
and NIS - Centre of Excellence
via P. Giuria, 7 - 10125 Torino (Italy)
Tel. +39/011.670 83 85 -Fax +39/011.670 78 55
ugo.finardi@unito.it

ABSTRACT. Nanosciences and nanotechnologies (NST) are a developing scientific-technological area in full expansion and evolution. Their character of General Purpose Technology has been assessed. Asian countries play a relevant role in the evolutionary path and growth of NST, as in some cases they present a rapid growth of scientific production. This work analyzes the performance of three of such countries – People's Republic of China, Japan, South Korea – emphasizing several aspects of their performance in scientific production and putting in reciprocal relations these aspects. Results show a different behaviour of Japan – which starting from a dominant position is loosing ground with respect to its competitors – and of the other two countries which are catching up. Insights on the internal organization and on the mutual relations are also offered, together with a comparison of the relation with other important areas of NST scientific production.

KEYWORDS: nanotechnologies, nanosciences, evolutionary trends, People's Republic of China, Japan, South Korea

JEL CODES: L6; O31; O33

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**Ugo Finardi* holds an MSc in Industrial Chemistry and a Ph.D. in Materials Sciences and Technology. He is at present Research Assistant at the Department of Inorganic, Physical and Materials Chemistry at the University of Torino and Fellow of Ceris-CNR. He performs research in the fields of Innovation Studies, with a focus on nanotechnologies, research and industrialization of new materials, technology transfer, regional systems of innovation and management of research.

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INTRODUCTION

The insurgence of nanosciences and nanotechnologies (NST) is one of the most important novelties in the panorama of scientific and technological research. In the last decades the exploitation of the peculiarities presented by materials at the scale of the nanometers – that is to say, just above molecular scale – has attracted a growing interest of the environment of scientific and technological research, and then also that of economists and management scientist given the implications NST are foreseen to offer to the economic change, to the production activities and to the society at large.

This growth in importance and in received attention has not yet led to the exploration of every possible aspect of their past evolution, present status and possible future aspects. In particular an important theme to be addressed is that on the evolution of worldwide scientific production in NST under both points of view of time and space. Several authors have studied NST in the recent past, in order to analyze their features and to forecast possible future fall-out of their applications in innovation[1]. Nevertheless several topics are still uncovered and deserve specific attention in order to be elucidated.

The study of the evolution in performance of scientific production of prominent actors in NST research is still largely unexplored; this is particularly true for the study of emerging (from the point of view of NST research) countries, and of their comparison with countries yet assessed in the field.

[1] While the literature is not fully cited here for sake of synthesis, a list of references is found Huang et al. (2011).

This paper aims at contributing to fill this gap starting from the following research questions: how did evolve the performance in scientific production for three of the Asian leading countries in NST research – People's Republic of China (China from now on), Japan and South Korea – in the last decades? Which are their interrelations and their relations with other countries? How are their research activities organized?

The present work is organized as follows. A section dedicated to the theoretical framework defines what NST are, sketches their historical path, defines some important features, recalls the some recent contribute on the topic and previous studies performed on Asian countries. Methodology of data mining and research is then described in the following section, followed by an experimental section presenting obtained data. Finally results are discussed and conclusions are drawn.

1. THEORETICAL FRAMEWORK

NST can be defined as the ability to intervene on the matter at the scale of the nanometer (1/1.000.000th of millimeter) in order to exploit their peculiar features, both at the strict scientific level (investigation of the Nature in order to understand its behaviour) and at the technological level (exploitation of such behaviours in order to build objects useful for the development of mankind). Thus NST are classified on the basis of the dimension of the materials they develop and use and not by the exploited processes (Islam and Miyazaki 2009, p. 128), though it is beyond all doubt that some instruments such as the Atomic Force Microscope are peculiar to NST (Bonaccorsi and Thoma

2007). Actually the way followed in order to exploit the behaviour of the matter at the nanoscale is not always the same, as either "top-down" or "bottom-up" technologies can be exploited (Balzani 2005) depending on the attitudes of the operating scientists/technologists.

The first idea of exploiting features of the matter at the nanoscale is attributed to Feynman (Feynman 1960), while the first to use the word "nanotechnology" has been Taniguchi (Taniguchi 1974). Important points in the development of NST have been the invention of Scanning Tunneling Microscopy (Binnig and Rohrer 1986) and of Atomic Force Microscopy (Binnig et al. 1986), and the discoveries of Buckminsterfullerene (Kroto et al. 1985) and of Carbon nanotubes (Iijima 1991). The scientific production in NST has then been growing steadily since 1990 (Porter et al. 2008; Coccia et al. 2010; Kostoff et al. 2006).

One of the core characters of NST is its transversality. NST draw basic knowledge and experimental behaviours from the classic scientific fields of chemistry, physics, engineering, material sciences, biology. In fact, when dealing with NST, more than with a specific sector in sciences, technologies, and industries, we deal with a way of action in approaching the matter and intervening on it, the peculiarity of this approach being the intervention at the nanoscale in order to exploit the characteristics that are proper to the matter when manipulated in this scale. Consequently, the inventions coming from nanosciences, and the applications that might spring out from nanotechnologies, can virtually produce innovation in any industry and in any field of application.

This is the basic reason why nanotechnologies have been defined a "General Purpose Technology" (GPT), a term assigned to core technologies – like electricity at the beginning of the XXth century and microelectronics at the end of the same century – having an extensive and pervasive effect over the society at its whole. GPT are defined by Bresnahan and Trajtenberg (1995) as characterized by the potential for pervasive use in a wide range of sectors and by their technological dynamism.

Shea (2005, p. 188), given the volume and breadth of applications, proposed nanotechnology as a GPT with various degrees of impact on industries, from radical change to incremental nature to complementarities with existing technologies.

Analysis of patenting is often exploited to give empirical evidence of GPT (Hall and Trajtenberg 2006). Youtie et al. (2008) did perform an analysis of patents and patent citations in order to explore the characters of nanotechnologies, but did not assess univocally the character of GPT.

Schultz and Joutz (2010) studied USPTO nanotechnology patents, affirming the development of general nanotechnologies for a wide range of sectors, as did Shea et al. (2011) who affirm the importance of defining nanotechnologies as a GPT in order to forecast their future trajectories.

Moreover NST are one of the "converging technologies", more specifically one of the NBIC (Nanotechnology, Biotechnology, Information technology, Cognitive science) technologies whose importance is foreseen as fundamental for the future. Actually possibilities for coordination of converging technologies at the global level have been suggested (Roco 2008) in order to exploit them at their maximum and to help solve several social problems that are underway at present (Roco and Bainbridge 2005).

The evolution of NST has been investigated in recent years. Meyer (2007), supporting his statements with a patent data analysis, affirms that (p. 782 and hereafter): nanotechnologies are not one but several fields of technology; there is no widespread but intermittent (punctuated) interaction between science and technology; instrumentation is a connector of fields; changes in NST tend to be incremental rather than discontinuous.

Miyazaki and Islam (2009; 2010) put in evidence the technology fusion trajectories related to nanotech as an important driver for innovation, which nevertheless demand for intensive research activity, showing that the fusion path is different depending on disciplines and presents similarities and disparities also from country to country. The multi-sectoral character of NST has as a consequence the need for several approaches in order to explain their evolution dynamics: there is not a one-direction technology evolution, but rather the interaction of different domains (2010, p. 231). Different sectors – Bionanotechnology, Nanoelectronics, Nanomaterials and Nanomanufacturing and tools – evolve under different trajectories, with US showing a leading role in the fast-growing biotechnologies, EU a stronger activity in nanomaterials, and the Asian countries playing the role of catching-up actors.

Mangematin et al. (2011) analyze the role of large incumbents entering the market of nanotech applications, with particular attention to subsidiaries of large companies. Their findings show that large firms are developing pre-adaptation in order to hybridize their knowledge base with emerging nanotechnologies (p. 13).

Finally, in order to correctly shape the theoretical framework previous studies on NST in Asian countries are introduced.

Miyazaki and Islam (2007) show that yet in the first part of the 2000s Asian countries were playing an important role in the global nanotechnology research (p. 673): Japan was in a the dominant position, while China was involved in a catching up process.

Youtie et al. (2008) study the positioning of several countries with respect to their scientific performance. Their analysis encompassed Europe, US, China, Japan and three “Asian Tigers” (South Korea, Singapore and Taiwan) as a bloc with data ranging from 1990 to 2006 (estimated). The increase of publications of “new” Asian Countries is witnessed, taking a bigger share of the total, with quality-based measures giving the same perspective as do quantity based ones (p. 985). This work seems so far to be the only one to confront the three countries of our interest (though South Korea is merged with other two Asian countries).

Huang et al. (2011) analyze past literature on NST, showing that (p. 154) benchmarking literature pointed out the leading role of the US, while Europe and Japan were not falling behind and new players (such as China and South Korea) were entering the race. They assert that such players did lag behind in key aspects, as for instance quality of publications for China.

A patent analysis study, delineating the role of Asian countries in nanotech patenting, has been performed by Dang et al. (2010) who have found a large growth rate of nanotech patents (larger than for scientific articles), with a huge contribution from China, Japan and South Korea, and from the US.

Though the study of scientific and technological performance in NST of Asian countries has been so far performed by some authors, it is still under covered in several of its aspects. Moreover an analysis of the relations between such countries and a comparison of their performance is still lacking. This paper contributes to fill this gap.

2. METHODOLOGY

In order to obtain data on the NST scientific production of China, Japan and South Korea the Scopus database[2] was exploited. Scopus was preferred to other analogous databases because:

- *It encompasses a wider set of data*: more than 18,000 titles (17,000 peer-reviewed journals plus other sources) are present in the database[3];
- *It has the broadest available coverage*: titles from all geographical regions are covered, including non-English titles as long as English abstracts can be provided; approximately 21% of titles are published in languages other than English or published in both English and another language; more than half of content originates from outside North America; more than 1500 journals originate in the Asian pacific region;
- It has a wide set of data retrieval instruments, useful in performing data mining: selection of data of scientific products can be refined through the selection of source title, publication year, author name, subject area, document type, keywords, affiliation, source type, language.

Data mining from Scopus was performed in February 2011 using the following methodology:

a) First the search of "nano*"[4] on "Article Title, Abstract, Keyword" was made;
b) Then on the selected records a further refinement is performed using the "Refine results" frame, selecting only those records containing one or more of the following keywords: "Nanostructured materials", "Nanotechnology" or "Nanostructures".

The target was to obtain a set of scientific products as much wide as possible but having without any doubt a direct connection with NST with the use of a simple methodology. In order to obtain this result the three most represented keywords of general NST meaning were selected. Moreover this methodology was also intended at avoiding biasing caused by the use of keywords related to NST research activities that might be more localized in specific geographic areas.

In particular, data mining is performed on:

- Time Horizon from 1990 to 2010: Scopus database goes beyond 1990 (though data on citations are complete

[2] http://www.scopus.com/

[3] The source for this introduction on the exploited data source is: http://www.info.sciverse.com/documents/files/scopus-training/resourcelibrary/pdf/sccg0510.pdf (accessed february, 2011).

[4] "*" is the usual dummy meaning "any series of character after the ones written"

from 1996 onwards), but the huge growth of scientific production in NST starts from mid-1990s. Years from 1990 to 1995 were considered in order to have a wider horizon. 2010 instead is the last available year (as data mining was performed in February 2011). A caveat is the fact that the short time lag between end of the year and data harvesting might in some way bias the results for this last year. This time horizon gave the possibility to analyze spatial and temporal evolution of scientific NST production.

From the general obtained dataset, encompassing more than 178,000 scientific products, data on the different geo-economic key areas were extracted exploiting the "Advanced search" tool, inserting the name(s) of the country(es) in the search string.

- *Key geo-economic areas*: beyond the three areas subject of this work, also data regarding North America (USA and Canada) and Europe[5] were retrieved, in order to analyze their relations with the three studied countries, given the fact that these two regions are still the main worldwide players in the production of NST research activities. Such data were retrieved with the use of combined queries, inserting the name of the two countries/geographic area in the query text under the tag "country". To do so the "Advanced search" option of Scopus was exploited.

[5] In "Europe" the selected countries are: Albania, Austria, Belarus, Belgium, Bosnia, Bulgaria, Croatia, Czech Republic, Estonia, Finland, France, Germany, Greece, Holland, Hungary, Ireland, Italy, Latvia, Lithuania, Macedonia, Moldova, The Netherlands, Norway, Poland, Portugal, Romania, Russia, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, and United Kingdom.

Data on affiliations of research institutions producing results of research in NST were also exploited.

Using this procedure a full dataset of the scientific NST production was obtained.

3. EXPERIMENTAL SECTION

In this section obtained data, relative to the three countries subject of this article, to their inter-country relations and to the relations with other key actors, are presented.

The overall NST scientific production of China, Japan and South Korea is presented in table 1, containing figures on the evolution of the scientific production for the three countries and for the global world NST production. The behaviour of the three countries is similar, with some slight differences, and respects the general behaviour of the world's production.

A more powerful analysis of differences between the three countries can be performed studying the evolution with time of the fraction in percent of NST scientific production for the three countries over the world's production (Figure 1) in the years from 1994 (when figures started to be relevant) onwards. Here the differences in behaviour are more striking: data show that, while Japan was starting from a dominant position at the beginning of the evolution of NST, it has quickly lost its dominant role on the overall world production. In the meanwhile the other two studied countries, China and South Korea, have grown steadily in the share of world's market of NST scientific production.

These results might nevertheless be biased by a factor put in evidence in table 2. Chinese scientific production – as reported by Scopus – has been published (in years 1990 – 2010) in mother language for more than 13 per cent of the total national production. This figure almost doubles that of Japan, and is almost thirty times that of South Korea. Thus, though the majority of scientific production remains in English, feasibly on international journals, a certain rate of scientific products directed towards the internal market must be accounted, biasing the results of the share of world's production.

International collaborations, both at inter-country level (that is to say between the three Asian actors) and at world level (with the other prominent world actors Europe and North America) have been analyzed.

Figures 2 and 3 show data on inter-country collaboration (among the three Asian countries) and date on collaborations with the two other leading areas. The set of inter-country relations is unbalanced, and sees strong differences in the triangle, as put in evidence by table 3. Nevertheless the most important result is the count of percentages (last line in table 3), that shows that inter-country collaborations between the three studied Asian countries are only a slight percentage of the total production of the three countries. The result is even more striking if we consider the geographical proximity of the three described countries.

If we then analyze the rate of collaboration with Europe and North America further results can be obtained. Figure 2 presents data on inter-country collaboration together with data on collaboration with these two main international actors. Data start from 1995 as no scientific products written in collaboration are present before this year. Collaborations for China are slightly more that those of the other two countries; while China and South Korea tend to collaborate more with USA and Canada than with Europe, the opposite is true for Japan. If we plot the percent of scientific products written in collaboration with the two external actors over the total NST scientific production of the three countries we obtain the graph of figure 3. Table 4 shows data for the three Simple linear regressions performed on the three lines[6]. The rate of collaboration is bigger for South Korea, whose intercept is above 10, followed by Japan and then by China, with an intercept less than half that of South Korea.

Figure 2 presents another result of interest. It is easily seen that, in spite of the geographical proximity, the rate of collaboration of the three countries is always bigger when involving USA and Canada and Europe than when involving one of the other two countries object of this study.

In order to assess the quality of scientific production, citations received by scientific products from the three countries were retrieved. Data on the total (absolute) value of received citations per year were retrieved and averages per each scientific product were calculated. Average data are plotted in figure 4. The absolute number of citations received by the scientific products of the three countries published shows slightly different trends for the three countries. If we analyze the average citation number per patent differences become more striking. Simple linear regressions performed on the plots of average citations received vs. year of

[6] A caveat about performed linear regression performed here and below must be taken in account, as time series are relatively short and migh thus bias the obtained results that must be then handled with due care.

publication show three different behaviours. Japan trend line starts very high, but its trend is negative. China and South Korea trend lines start at a much lower level, but their trends (especially that of South Korea) are positive. In order to study the effect of possible biases (earlier beginning of production, decay of received citations in the last period) further Simple Linear Regressions performed on different time spans (table 5) give results in line with the previous one. Japan always presents an Intercept higher and an Angular Coefficient smaller than the other two countries, who present similar smaller intercepts and a higher Angular Coefficient, with South Korea growing faster than China.

In order to analyze the internal organization of NST research in the three countries and its evolution over time, Herfindal-Hirschman Indexes (HHI) for national affiliations present in the database were calculated for the three countries for the years 2000 – 2010.

The HHI is defined as:

$$\text{HHI} = \sum_{i=1}^{n} (s_i)^2$$

Where:

$s_i =$ market share (%) of the i^{th} firm

and in this case

$s_i =$ share (%) of scientific production over the total national production of the i^{th} affiliation.

Thus, the higher the value of HHI, the higher is the concentration of scientific production in fewer research centres. Values for HHI range (when using market shares in %) from 0 to 10.000: this is the case of total monopoly, where a single firm (research centre in our case) produces 100 % of market share.

In order to calculate the HHI the approach of Nelson (1963) was followed: Nelson, when calculating the market concentration in the manufacturing industries of the United States, did take in account the first 50 firms for each industry market. We did follow the same approach in this study, thus summing up shares of NST production up to the 50^{th} research affiliation of the country subject of the analysis. A further rationale for this approach is the fact that in all cases the 50^{th} value of the list is around or less the 5 % of the value of the most productive affiliation in the year. Thus we could consider the research affiliations with lower values as “out of the market”, that is to say working only marginally on NST. Results of this analysis are plotted in Figure 5; table 6 reports data for the Simple Linear Regressions performed on the trend lines.

While values of HHI are relatively low (always below 1200) the trends for the three countries show strong differences in their evolution over time.

South Korea presents a high concentration of scientific production, with a high value of HHI which, after 2001, decreases slightly to a value just above 600 (56 % of the initial value). The decrease of the trend line is not continuous, but the angular coefficient of the regression is the more negative of the three (feasibly also due to the very high initial value). Nevertheless in the second part of the trend line (from 2006 to 2010) the HHI of South Korea is around the values presented by Japan.

Japan and China start in 2000 from similar values, but their behaviour over time is totally opposite. The HHI for Japan grows more or less steadily and reaches in 2010 a value which is about 50 % greater than the starting value of 2000. China, conversely, presents a steady decline of the values of HHI, and the value for 2010 is around one/third of the value for 2000.

If we cut off years 2000 – 2002 from the analysis (Simple linear regression data are reported in Table 6) we easily notice that the behaviour of Japan changes, with a very small (negative) angular coefficient: the evolution with time of the concentration of scientific productivity in NST becomes stable around the same values. Changes presented by China and South Korea trend lines are less important.

The above described data must be considered jointly with the plot of the values of HHI against the correspondent number of scientific products for each year. The results are presented in figure 6. Again the three groups of points show a very different behaviour. For China low values of HHI (and thus a low rate of concentration of scientific production) correspond to high values of productivity. This behaviour is similar to that of South Korea, where – although presenting lower values of production and higher values of HHI – again the highest productivity is associated with lower values of HHI and thus greater dispersion of scientific production. Conversely in Japan higher productivity is associated with higher rates of concentration of scientific production and towards the tendency to a monopolistic situation. Japan data are roughly divided in two parts: in years 2000 – 2002 the HHI is around 400, and the production is lower (around 1.000 products), thus forming a smaller cluster; in years 2003 – 2010 HHI grows slightly and oscillates around 600, with a production above 2.500 products (but for one case). Production of China presents a similar behaviour, with two groups of points (beyond and above 2.000 products), while HHI is less discontinuous. The case of South Korea – apart from the data of year 2000 – is quite different, with a single cluster of points marking a decline of HHI with productivity.

4. DISCUSSION OF RESULTS AND CONCLUSIONS

Aim of this paper was the accurate analysis of the aggregate scientific production in nanosciences and nanotechnologies (NST) and the exploration of its evolution over time of three Asian countries leaders in the field: China, Japan and South Korea. The analysis was performed on a timespan of twenty years, from 1990 to 2010, that is to say, from the very beginning of the insurgence of NST as a field of research. The three countries were chosen as they are among the current leading producers of NST scientific literature in the world.

The results of the experimental activity show several points of interest and differences in the evolution over time of the scientific production of the three countries. The overall production grows in all the three countries according to the global world production, but the increase in bigger in China – which presents also the greatest absolute value of published scientific products – and in South Korea with respect to Japan, whose production shows a much lesser increase. Percent shares of the global production show that, while the share for China and South Korea increases steadily, the share of Japan falls down constantly from 1994 onwards. Share of production in mother language is much higher for China, which produces almost the double of Japan and almost thirty times of South Korea in its own language. Thus a part of this increase for China could be due to the production of scientific literature only for the national science environment.

Data on collaborations with other countries (both among the three studied ones and the other major scientific contributors to the world's production in NST) show a very low rate of scientific collaboration performed amongst the three Asian neighbours. The number of papers co-authored with European or North American colleagues is also low but it outnumbers the figures for inter-Asian countries papers. Nevertheless the number of collaboration of China, Japan and South Korea with North America and Europe grows steadily from 1995 onwards.

A measure of the quality of the production was performed using data on received citations and on their evolution. This measure undergoes a series of bias, but as far as now is the only exploitable and measurable index of quality of scientific production. The absolute number of citations grows steadily for the three countries and shows a peak in 2003 for China and Japan, and in 2007 for South Korea. The most meaningful measure is nevertheless the average number of received citations per produced item. Here the evolution with time of the three countries shows some differences. Japan presents a higher value of average received citations in the first years of our database, but presents also the fastest decrease in received citation or, taking in account only a part of the explored time span, the slower increase. South Korea, though starting from lower values of received citations, sees the biggest increase in received citations along with time. The case of China is intermediate, as the initial values (the intercept) are around those of South Korea, and the evolution with time, though the increase is superior (or, depending on the time span, the decrease is inferior) to that of Japan, values are beyond those of South Korea. Values in the last years are around those of Japan.

Other significant results come from the analysis of the evolution of HHI. Values of HHI are below 1.000, indicating in general a high rate of dispersion and a competitive national scientific environment for all the three nations. China presents a continuous decrease of the HHI from 2000 to 2010, thus showing the continuous entrance in the "market" of NST scientific production of new research centres/research institutions/ laboratories, causing the steady decrease of the market shares of the internal NST production: this situation resembles that of "creative destruction" with new entrants continuously entering the market. A similar behaviour is that of South Korea, which, though presenting values of HHI around three times those of China, also present a decrease; the main difference is in the fact that the decrease for South Korea is not as linear as that of China. The trend of Japan is, also under this point of view, opposite, as research production tends to concentrate or, if we do not take in account the first years of the series, to remain more or less stable.

What is even more interesting is the plot of HHI versus production. In fact for China points in the graph indicate (roughly) a growth in production associated with a decrease of HHI and, thus, with a greater dispersion of "productive activities”; this trend is roughly replicated by data for South Korea, while the opposite is true for Japan, where greater concentration is associated with higher productivity.

Summing up the results the following conclusions can be drawn:

- China presents the highest scientific production in NST in terms of absolute value and of share of the world’s total; this fact is associated with the highest growth in both magnitudes. Nevertheless, a high share of this production is in mother language, thus affecting only partially the world’s scientific community.
- Japan presents a smaller production and a growth rate smaller than China, and a decrease in the world’s share of production.
- South Korea has the smaller production and a growth rate (both in absolute value and percentage) bigger than Japan and smaller than China.
- South Korea has also the best result for received citation per paper, particularly for what about the evolution of the trend.
- China presents values of received citations lower than those of South Korea, but still a positive trend.
- Japan did present the best performance in the 1990s, while in the following period its performance did align with those of the other two countries, thus marking a stabilization.
- Very different trends for the internal market of NST scientific production are present, with China presenting a growth in the dispersion in many research centres associated with a growth in production, Japan an opposite trend with a progressive concentration generating more products and South Korea a higher rate of concentration, a trend towards dispersion parallel to the case of China and a production path less dependent by growing dispersion.
- The three countries tend to avoid scientific collaboration with closer partners, preferring – though the incidence is still small – scientific partnerships with further main actors. South Korea is the leader in this trend (equally growing for all the three cases). This last fact is lined up with the findings of Coccia et al. (2011).

When coming to the analysis of the causes of the above described facts, we find a multiplicity of answers. Japan assessed itself in scientific production earlier than its Asian partners, and this could account for the progressive decrease/stabilization of its shares in production and citations received. Moreover the presence of a yet stabilized structure of research centres could account for the behaviour of the trend line of HHI. China and South Korea, conversely, may present a more dynamical situation of “creative destruction” with higher rates of market mobility and new entrants. Under this point of view the dimensions of countries under the points of view of population and of geographical extension might play a determinant role. For what about dynamism of the scientific environment, South Korea, in particular, presents the characters of the highest share of international collaborations and of the smallest number of publications in mother language, thus presenting itself as the country with the most outbound attitude.

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TABLES AND FIGURES

Table 1: *NST scientific production per year*

Year	*World*	*Japan*	*S. Korea*	*China*
1990	27	1	0	0
1991	8	3	0	0
1992	13	2	0	0
1993	32	3	0	1
1994	218	32	4	14
1995	1.602	192	17	143
1996	2.107	325	30	198
1997	2.499	373	40	252
1998	2.671	380	56	343
1999	3.361	512	100	372
2000	3.845	512	105	502
2001	5.486	730	187	683
2002	8.561	1.013	315	1.041
2003	12.958	1.518	619	1.670
2004	18.843	2.110	927	2.587
2005	24.477	2.661	1.161	3.690
2006	26.249	2.874	1.714	4.821
2007	16.007	1.367	977	2.855
2008	23.289	1.913	1.423	4.261
2009	14.651	982	809	2.832
2010	14.124	849	850	2.860
Total	*181.028*	*18.352*	*9.334*	*29.125*

Table 2: *Share of scientific products in mother language, 1990 - 2010*

	China	*Japan*	*South Korea*
Share of scientific products in mother language, 1990 - 2010	13.11%	6.75%	0.44%

Table 3: *Inter-country NST prod., 1990 – 2010: abs. value and percentage*

	China + Japan	*China + S. Korea*	*Japan + S. Korea*
Inter-country NST prod., 1990 – 2010	794	247	448
Total NST prod. 1990 - 2010	47477	38459	27686
% inter-country collaborations	1.67	0.64	1.62

Table 4: *Linear regressions data for regressions performed in Fig. 2*

	Ang. Coeff.	*Intercept*	R^2
China	0.50	4.48	0.71
Japan	0.52	7.86	0.52
South Korea	0.50	10.30	0.28

Table :5 *Evolution of received citations: linear regressions performed on diff. time spans*

	1990 – 2000			*1995 – 2010*			*1994 – 2003*		
	Ang. C.	*Int.*	R^2	*Ang. C.*	*Int.*	R^2	*Ang. C.*	*Int.*	R^2
China	0.15	7.54	0.01	- 0.89	19.24	0.30	1.89	5.40	0.86
Japan	- 0.41	18.07	0.11	- 1.53	27.62	0.80	0.09	19.61	0.00
South Korea	0.39	7.88	0.06	- 0.83	22.62	0.22	2.34	5.93	0.85

Table 6: *Evolution of HHI: linear regressions performed on diff. time spans*

	2000 – 2010			*2003 - 2010*		
	Ang. Coeff.	*Intercept*	R^2	*Ang. Coeff.*	*Intercept*	R^2
China	- 28.20	470	0.89	- 36.60	433	0.95
Japan	20.86	421	0.50	- 0.93	603	0.00
South Korea	- 33.45	920	0.52	- 20.78	759	0.37

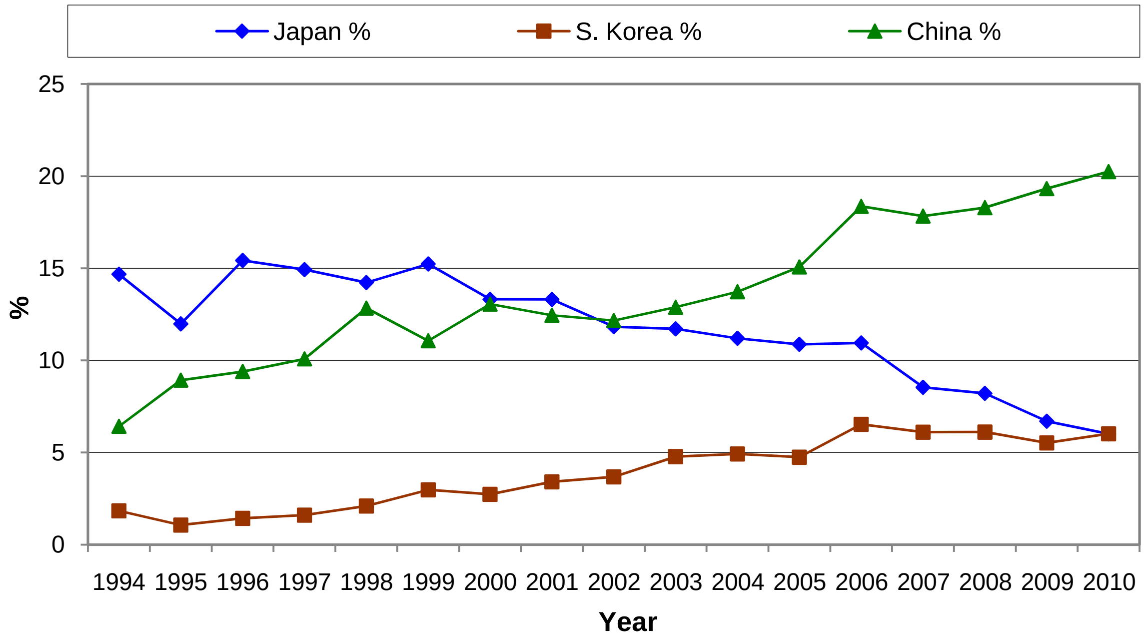

Figure 1: *Fraction of NST scientific production over world's production over time, years 1994-2010*

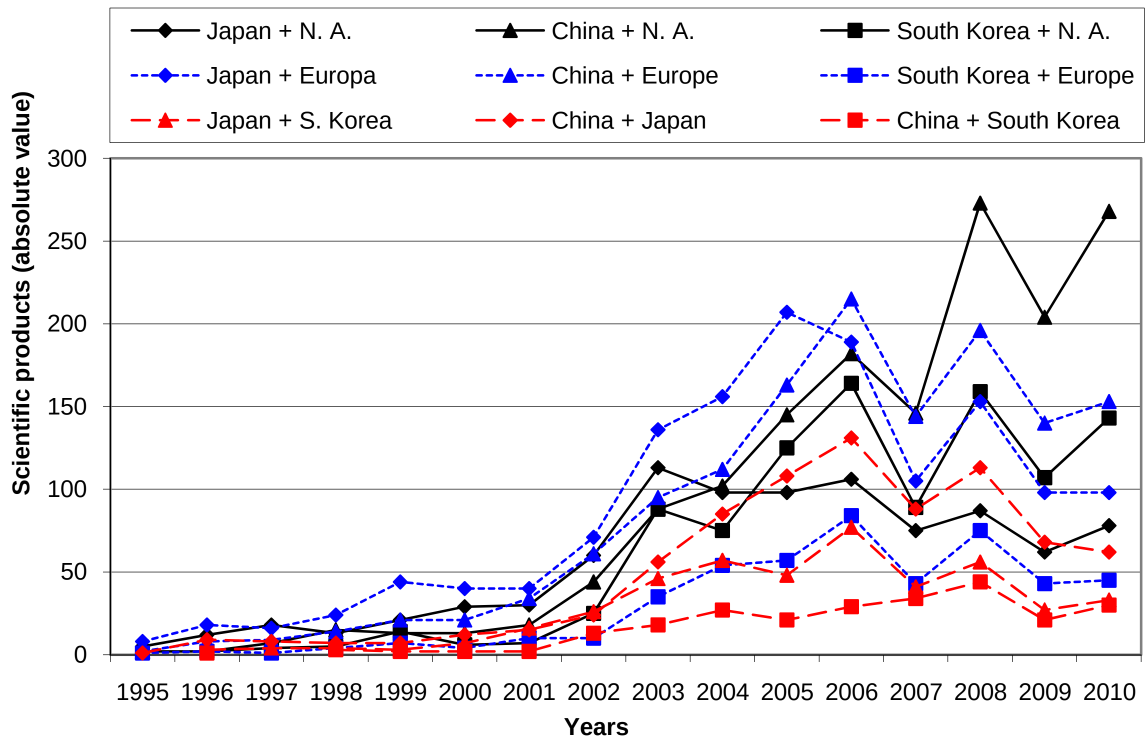

Figure 2: *NST Scientific products written in collaboration with N. America and Europe and between the three countries: evolution over time, years 1995-2010*

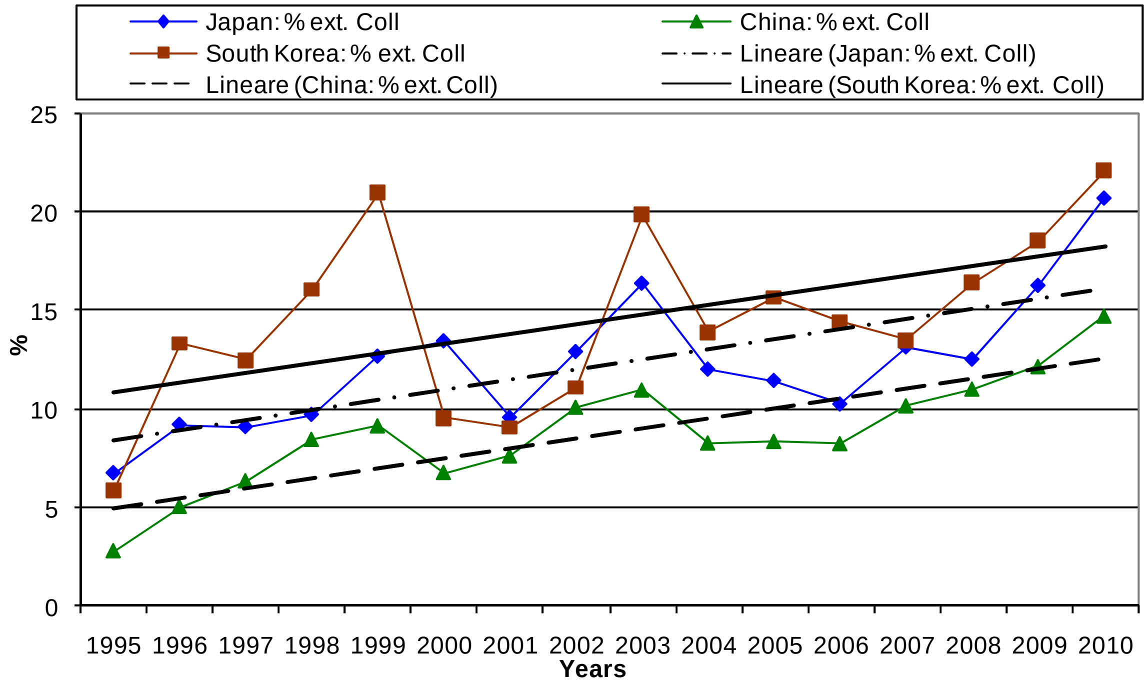

Figure 3: *Fraction of NST scientific products written in collaboration with N. America and Europe: evolution over time, years 1995-2010*

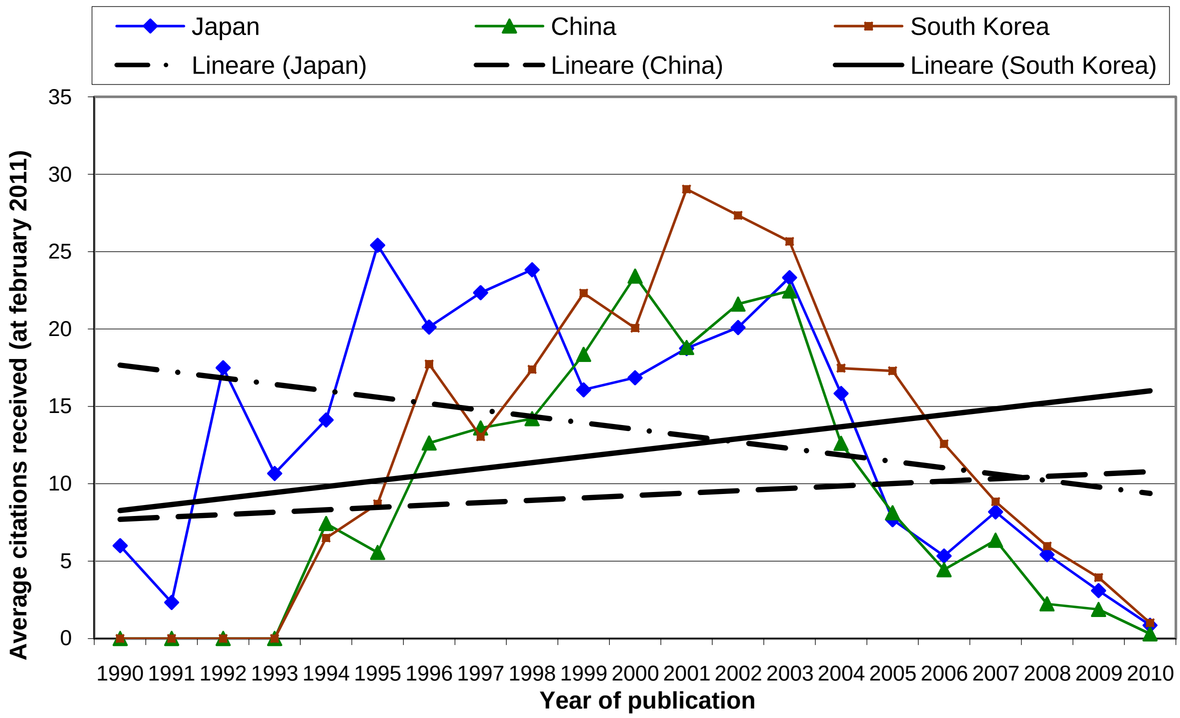

Figure 4: *Average citations per paper per year of publication, years 1990-2010*

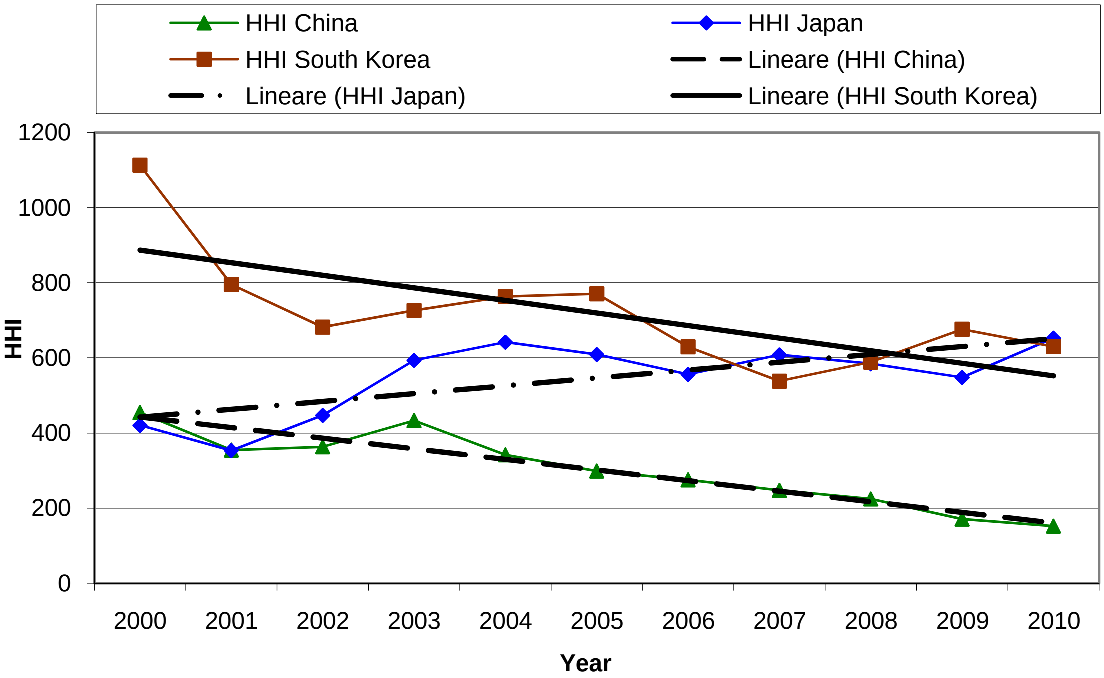

Figure 5: *Herfindahl - Hirschman Index for the three countries, years 2000-2010*

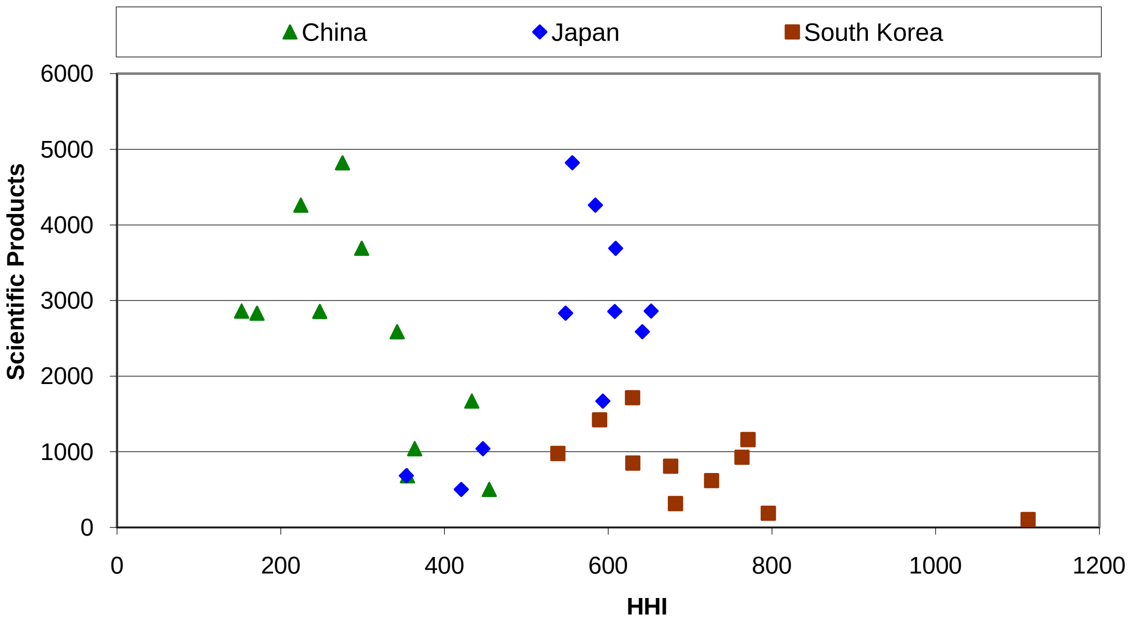

Figure 6: *Herfindahl - Hirschman Index vs. Productivity, years 2000-2010*

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