Mapping international knowledge flows

Three dimensions for a framework to evaluate transnational cooperation in research

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1 Context

The internationalization of science and technology (S&T) has increased in the last few decades, and magnified the tension between national systems of innovation (NSIs) and transnational technology. This internationalization of science and technology has two main drivers : the cosmopolitan nature of science, which connects universities from different NSIs, and the international operation of large transnational corporations (TNCs). The shift that has taken place in the production and application of scientific knowledge has important implications for countries in the South. This study investigated the current level of tension between NSIs and transnational technology, and explored the evidence for the rudiments of a global innovation system. The conjecture was that the level of internationalization of S&T achieved thus far might be underestimated. This may explain why there is only limited literature about a global innovation system. An important public policy challenge for the South is how to support domestic investment in S&T and ensure inclusion in international knowledge flows.

2 Empirical Methods and Main Findings

Three avenues were pursued to investigate the rudiments of a global system of innovation : transnational corporations and their networks of firms and subsidiaries, which are a source of significant knowledge flows ; international patents, which offer

information about cross-border knowledge flows ; and international cooperation in the authorship of scientific papers.

An emerging global innovation system — Current changes in the global economy stress the growth of both internationalization and knowledge about economic dynamics. Those combined changes —with positive feedbacks between them — prepare the ground for an emerging global innovation system. There is a considerable and growing literature on the internationalization of R&D that suggests there has been an increase in the level of internationalization of R&D and international knowledge flows. However, recent statistical analysis of the internationalization of R&D suggests that this process might have reached a turning point. A question emerges : can we actually capture all forms of internationalization that are taking place ?

TNCs are key entities that connect different NSIs in very dynamic ways through both subsidiaries and universities distributed in different countries. Of course, the specific knowledge flows around or within TNCs do not include all possibilities. Science in itself is an international endeavour, exemplified by the foreign exchange of students, scientists, books, and papers. International collaboration in science, as measured by papers with co-authors from different countries, is growing. TNCs may now have the ability to connect research efforts globally, using channels of information that go beyond published papers.

Other indirect relationships may exist between a TNC and a foreign university through a local firm that interacts with a local university and has a technical or economic relationship with a firm headquartered abroad. Another international flow might be an acquisition by a TNC of a firm that is a spinoff from a foreign university. This mosaic of international knowledge flows clearly illustrates the diverse sources of tensions between transnational technology and NSIs.

3 Empirical Approach and Main Findings

TNCs and their subsidiaries — The spread of networks of TNC subsidiaries multiplies the sources of internationalization. As multinational companies continue to develop international networks to exploit foreign centres of excellence, these networks become the basis for productive and innovative global networks. Data from Orbis, a database that collects information about private companies in a wide range of countries, was used in this study. The database covers more than 96 million companies in 210 counties. Almost 90% of these firms are from the manufacturing industry, which consists in all enterprises not listed as financial, insurance, or as any type of commercial business, including non-financial services. Data from more than 1400 variables grouped in 21 categories can be obtained about these companies.

The data used was a subgroup of the Orbis data. The concept of Global Ultimate Owner (GUO) was used to identify companies that either directly or indirectly own more than 50% of their working capital. Companies controlled directly or indirectly by a GUO were considered subsidiaries. In this case, a subsample of 874 of the world's largest GUO, ranked by number of employees, revenue, and profit, were selected. Theses GUOs controlled 139,541 subsidiaries, of which 87,344 operated overseas and

were ultimately controlled by 784 multinational enterprises (MNE). The home country of the largest number of GUOs was the USA, with 262 companies, followed by Japan with 211 companies, the UK with 58 companies, and Germany with 44 companies. In all, 55 countries hosted the headquarters of MNEs, of which 26 were developed countries and 29 were developing counties. Considering foreign subsidiaries, the USA is home to 232 companies and hosts 412 GUOs controlled by foreign countries.

The ranking of countries by the number of MNEs did not differ significantly from that of the total number of GUOs. Considering subsidiaries only, 262 GUOs located in the USA controlled 47,695 companies, of which 25,036 were located abroad. The UK hosted the largest number of foreign subsidiaries (9417), which are controlled by 511 GUOs around the world. The USA hosted 9161 companies, which were controlled by 412 GUOs abroad. The ratio between the number of subsidiaries controlled abroad and the number of subsidiaries hosted provides clues as to each country's status in terms of internationalization. For example, this ratio for the USA was 2.7. This is in stark contrast to Japan, where the ratio was over 10. The same ratio for Europe as a whole was 1.2, and ranged from 0.7 for the UK to 3.8 in Switzerland. When developing countries were considered as a group, the ratio was 0.5, consistent with an inward pattern of internationalization. However, some countries, such as South Korea and Taiwan, had ratios of 1.4 and 1.5 respectively, which were a lot closer to European standards. China was a case apart with a ratio of 0.06 (it hosted 4436 subsidiaries, but its TNCs controlled only 278 subsidiaries abroad).

Advantages stemming from access to capital, scale economies, organization, technology, and expertise in international operations, allow firms to overcome barriers of entry to foreign markets. Therefore, the number and the variety of countries in which subsidiaries of MNEs operate can indicate the advantages of the host country that can be exploited by companies from abroad.

Triadic patents as indicators of international flows — Triadic patents are patents that are filed for the same invention in the USA, Europe, and Japan patent offices. While their value is debated, they serve as a useful guide to evaluate technological performance of nations and sectors. Patstat's database, with data from 2000 to 2010, was the source of data on triadic patents. Four established and two new internationalization measures were used. The four established measures are : assignee-author, GUO-assignee, co-author, and co-assignee. In addition, the two new measures were : citation of foreign ISI-indexed papers, which grew from 1.5% in 2000 to 2.5% in 2010 ; and the citation of foreign patents, which in 2000 showed that a total of 88% of the triadic patents had at least one citation of a foreign patent, a proportion that peaked at 2005 with 91% and in 2010 was in 90%.

Regarding the four internationalization indicators used in the literature, the results for 2010 were : international flow Assignee-Author 11% ; international flow GUO-Assignee 4% ; international flow co-authorship 7% ; and international flow Assignee-Assignee 1%. These data are higher than reported in the literature. There has been a consistent increase in patents with non-patent references (NPRs) — from 53.7% in 2001 to 69.5% in 2010. Those NPRs may be a source of important information about the relationship between technology and science and engineering fields.

ISI-indexed papers and TNCs in international flows of science —Data on co-authored papers between universities and research institutions in different countries reveals linkages between different systems of innovation. According to the National Science Foundation (NSF), in 2012 the world published 2,019,563 ISI-indexed documents (articles and abstracts) and 329,190 had at least one cross-border co-authorship (16%). The USA led in both papers and papers with international co-authors. The main difference compared with the ranking of patents is China, which was in second place in terms of both total articles and articles with international co-authors. Countries at the periphery generally moved down in rankings in total papers and internationally co-authored papers : India (from 9th to 17th), Brazil (from 13th to 15th), Turkey (from 16th to 30th), Iran (from 17th to 25th), and Russia (from 18th to 21st). These data suggest that immature NSIs have problems with their international connections.

International networks of scientific institutions connect different systems of innovation, and are a source for creating new international interactions with firms and universities. Firms also invest in basic science and publishing research results. Preliminary data analysis shows that at least 71,671 papers were published by firms (about 1.74% of global scientific production). Findings show that the leading firms are from the pharmaceutics and biotechnology and electronics and computing sectors, and include firms in Japan, China, and South Korea. Papers published by companies may involve three different types of international knowledge flows : a cross-border flow between two subsidiaries working together ; a flow between a MNE laboratory and a foreign university ; and a flow between a subsidiary and a local university. Co-authorship between firms in different countries showed that the majority are co-authored between two units within a transnational corporation.

South–South international flows — A preliminary evaluation was made of three different tensions between the international knowledge flows and the national innovation systems. The first source was the TNC itself. Transnational firms have grown larger and more global — 874 TNCs have 87,344 subsidiaries abroad. These subsidiaries are more distributed throughout the world and over time begin to have more autonomy and initiative, which leads to more interactions within the innovation system that hosts them. The size of those networks, which connect tens of thousands of subsidiaries, erodes the notion of a 'national'innovation system. The second source is the technological and innovative activities of transnational firms when TNCs integrate their subsidiaries in cross-border R&D to take advantage of specializations and contributions of different national systems of innovation. The third source is the scientific infrastructure, an increasingly international system that connects universities, research institutions, and firms. Research always crosses borders and integrates teams from different countries. The complexity of international networks increases the myriad of possible interactions between universities, firms, and research institutions.

This study presents some introductory hints about the participation of the South in international knowledge flows. Ten countries in the South ranked among the 30 leading countries with TNCs ; 7 countries in the South were within the 30 leading positions in the ranking of triadic patents ; and 9 countries in the South were among the 30

leading positions in the ranking of ISI-indexed documents. These relative positions are the basis for participation in international flows.

Regarding TNCs and their subsidiaries, 172 firms had their GUO located at the periphery, and among them, 148 TNCs also had subsidiaries located at the periphery — a total of 2766 subsidiaries were located at the periphery. Those South–South connections represent flows of tacit knowledge. Regarding triadic patents, international flows captured in cross-border patent citations showed the position of the South. In terms of pairs of countries sharing patents, South Korea and Taiwan were ranked 80th globally, with China and South Korea (87th), China and Taiwan (180th), India and South Korea (356th), Brazil and South Korea (384th), Russia and Taiwan (472nd), Taiwan and South Africa (474th), and China and India (510th). Of course, countries from the South that formed pairs with developed countries were in better positions (South Africa and USA 127th ; Brazil and USA 149th ; and India and USA 83rd). Regarding international co-authorship of ISI-indexed papers between countries, in the first 40 positions, there were 8 pairs with one country from the South. China's pair with the USA led the ranking. Pairs between countries from the South began at the position 68th (China and South Korea with 2056 papers). Other examples of South–South pairs were Egypt and Saudi Arabia (122nd), Brazil and Argentina (233rd), India and China (237th), Brazil and China (252nd), Iran and Malaysia (347th), Brazil and Mexico (348th), Brazil and India (387th), and Brazil and South Africa (459th).

The provisional conclusion is that the South has identified links with the ongoing process of internationalization of S&T, which are smaller than the links between developed countries. But the identified links show that the South is contributing to the broader internationalization process, a key component of the emerging global knowledge economy.

4 Main messages for policy and practice

The important shift in the production and application of scientific knowledge has deep implications for countries in the South (low and middle-income countries). There are two major implications : first, as technology becomes more dependent on science, significant investments in scientific infrastructure are a precondition for technological catch up ; and this growth in the scientific dependence of technology goes hand-in-hand with an increase in the internationalization of knowledge flows. Therefore, the South may be facing a new challenge as a consequence of an emerging global system of innovation. Those two major implications have one important public policy challenge for countries in the South : investments in S&T must be made domestically with a clear international strategy to promote international knowledge flows.

The research tools explored in this study may contribute to the planning and monitoring activities of policy analysts and decision makers. Further development of those tools may help understand sectors, S&E fields, and how a combination of challenges, weaknesses, and strengths may guide transnational collaboration in research and strengthen the formation of a global innovation system.

The use of different techniques to quantify and map international knowledge flows helps to evaluate the multidimensional nature of transnational cooperation in research. The use of information on TNCs, their headquarters, and the spread of their subsidiaries help to map the complex transfer of tacit knowledge, key for both new technologies and for putting forward new problems for scientific institutions — maps of those flows can contribute to an assessment of the resources of the South, and the direct links between countries at the periphery. The use of patent statistics highlighting how internationalized those flows have become an element probably underestimated in other analysis, and also indicated the presence of flows that link countries of the South. Finally, the analysis of ISI-indexed documents and articles, as predicted, indicated the most internationalized flows were those linking universities, firms, and countries.

Transnational flows of tacit and codified knowledge connect different NSIs and create the rudiments of a global innovation system. It is a challenge for policy analysts and decision makers who must begin to realize that this international dimension is a topic of growing importance and of relevance for the day-to-day activities of scientists and engineers.

Related Resources

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