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World Competences Capture by Multinationals in Environmental Technologies

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Abstract: This paper analyses how important is the capture of technological competences at global level in environmental technologies and its implications for the world technology transfer. Using data from the European Patents Office (1978-2010) and a classification for eight technological fields in environmental technologies, the paper concludes that the contribution to environmental technologies by multinationals is quite significant, but still concentrated in the triad countries. Outside the triad, the innovative activity in environmental technology is quite low and still leaded by transnational corporations. Emergent countries like Brazil, China or South Africa are more characterized by to be captured than to be capturers of technological competences inside the triad. This observation can be explained by a scarce numbers of domestic multinationals, a low R&D intensity by domestic agents and a low level of R&D internationalization outwards.

Keywords: Technological competences capture, multinationals, environmental technologies, technology transfer, patents, R&D internationalization

1. Introduction

The phenomenon of technological internationalization has registered strong changes along the last four decades. As the globalization process extended, the old called ‘Multinational Enterprises” (MNE) were becoming in a new type of agent which is recently called as “Global Corporations” (GC) (Pérez, 2012). There is a big difference between them. MNE led the mass production paradigm and emerged to extend mature domestic market outside national frontiers. GC was a result of the telecommunication and information paradigm and they act as structured production units in global scale.

Old MNE arose in sixties and expand until eighties by strong hierarchical structures. The process would be stimulated by the need to extend the production process until the final activities in foreign markets and to take advantages from lower costs located in peripheral economies. So, MNE made big overseas investments that, in many cases, were stimulated by local industrial policies. Under that scenario, MNE should not have a relevant role in technology transfer. Innovations efforts outside national frontiers were very low and internal flows of knowledge were mainly unidirectional from the headquarters to the subsidiaries. According to the MNE hierarchical structure, foreign innovative activities were directed towards technological development, while basic research remained close to the decisional centers of the corporation in the home country.

From nineties, the expansion of information and telecommunication technological paradigm changed radically this trend. Information begun to flow quickly and cheaply across the world and the hierarchical structures were becoming *networks* (Ghoshal and Bartlett, 1990; 1995). Modern GC can evaluate and identify the location of technological advantages in a world where, apparently, there is no frontiers to information and knowledge. Empirical observation of this new reality and the characteristics of these processes drove to new reflections about the technological internationalization. The role of subsidiaries is completely different in the new Global Corporations. Considering that the "foundations of competitive advantage no longer reside in any one country, but in many" (Kogut, 1989) and under a Penrosian view of firm, GC are now observed as *agents that capture technological competences in global scale* (Zanfei, 2000; Kapler, 2007).

During these decades, it was also observed a progressive deterioration of environmental conditions and an increase of environmental regulation by countries. Ecological issues were considered an important element of competitive advantages for many industries. The management of pollution and the use of energy minimizing ecological impacts became key variables. Firms started to be 'ecological' to improve the company image, reducing costs, etc., looking for environmental accreditations or greater market share (Arundel and Kemp, 2009). Additionally, environmental regulation also encouraged this kind of innovations (Ashford, et. al. 1985; Shrivastava, 1995; Ulph and Ulph, 1995; Jaffe, et. al. 1995 and 2002; Rennings, 2000; Rennings, et. al. 2006).

More recently, climate change and the degradation of natural resources have pushed the migration to a lower carbon pathway to reduce emissions of greenhouse gases (GHG) in the atmosphere (UNFCC, 2009). The adoption of the Kyoto Protocol in 1997, which entered into force in 2005, stimulated the development of these technologies and currently they are part of the global strategy for combating climate change (Glachant, et. al. 2009; Haščič, et. al. 2010, UNFCC, 2011). This strategy could include improvements in energy efficiency, but also advanced technologies for generating electricity or carbon capturing and sequestration (CCS). Some research works have concluded that the rate of innovation in the field of climate change mitigation technology has been mainly in technologies considered competitive such as wind power, some solar power, biofuels, geothermal and hydrothermal (OCDE, 2010, Dechezleprêtre, et. al, 2013) and it has been foreign direct investment (FDI) the main channel for the transfer of environmental technology.

Environmental technologies have the characteristic to be horizontal to industrial sectors deeply internationalized. In general terms, these technologies are produced by pollute industries (automotive, automobile, motors and engines linked to heating and refrigerating, chemical, ..) and other industries where those technologies are related to complementary assets, like in pharmaceuticals and health care. The technical know-how for pollution control resides primarily in firms in more developed countries. However, this knowledge can be disseminated to less-developed countries through FDI both to affiliates and to domestic suppliers and customers of Global Corporations (Popp, 2009 and 2011). In this context, corporations play a dual role. On one hand, they must assume the responsibility for emitting GHG, internalizing the cost of their production activities through a more proactive stance regarding their environmental management. On the other hand, and often as a result of new management strategies, they introduce new environmental innovations with the aim of reducing emissions through the development and dissemination of cleaner technologies or environmentally friendly technologies (Rondinelli and Vastag, 1996). Furthermore, corporations have developed clean energy projects, saving emissions in developing countries. This is the case of renewable energy or combined cycles that pursue to improve the production system inefficiencies and to increase productivity and competitiveness of the system.

Under this global situation, this paper aims to analyze the role of multinationals in the world capture of knowledge in environmental technologies, considering that capture involves taking knowledge from anywhere to be appropriated and transferred by multinationals that act globally. In this sense, the work tries to estimate the potential of technology transfer that network organizational structures permit across the whole world.

2. Global corporations and technology transfer

Capture of competences implies technology transfer with three characteristics. First, the *network* organizational model allows GC to transform unidirectional flows of knowledge (from the headquarters to the subsidiaries) in bidirectional (also from the subsidiaries to the headquarters). That constitutes transfer of knowledge by the internal networks. Second, technological capture can involve the development of foreign innovative efforts related to basic research and major ways of innovation. In order to this happens, technological competences that reside in host countries must to represent “frontier of knowledge” what usually involve being located in centers of excellence. Thirdly, multinationals can develop cooperative or contractual relationships with local agents to make effective the capture (external networks). In these cases, the capture of competences involves transfer of knowledge and acquires global dimensions. Let us go deeply in each one of them.

2.1. Bidirectional flows and limits

The hierarchical model stressed that the organization of R&D efforts would follow a center-periphery structure whereas the decision center would be located at the home country. Decision centers would radiate instructions and coordinate activities taking place in business units abroad. The decision centers also would select relevant lines of investigation related to the corporation core-business, carrying out basic R&D and transferring generic knowledge to be adapted by periphery R&D units. Periphery R&D-units in this model would be restricted to the performance of adaptive and applied R&D totally or mostly directed to marketplaces where they are located. Under this structure, knowledge flows should be unidirectional from the parent to affiliates and overseas technological efforts should mainly duplicate competencies (Rocha and Urraca-Ruiz, 2006).

Overtime, advantages of operating in different foreign markets that follow different rhythms and directions increased and firms begun to rise overseas applied R&D efforts to improve the interactions between productive, innovative and marketing and to overcome the obstacles to finance R&D locally (Papanastassiou and Pearce, 1995; Gerybadze and Reger, 1999). In this sense, the center-periphery model was being substituted by other, more decentralized, in direction to a network structure. Nevertheless, decentralized models do not always represent a *network organizational structure*. Networks contains some specific characteristics (Zander, 1998; Lööf, 2009): the multiplicity and heterogeneity of units executing R&D with some degree of independence of the parent firm; complexity in innovation processes; asymmetries of information; institutional and cultural differences; and, even when the results from one R&D unit can be directed to local users (local for local), they are mostly shared (transferred) by the whole corporation (local for global through the internal network). This latter characteristic demands a management system able to capture innovations produced by affiliates and to overcome communication, cultural and geographical obstacles.

One of the most emphatic critics to the decentralized organization of R&D is about the limits to intra-firm knowledge transference (Hirschey and Caves, 1981; Coombs, 1996). According with Persson (2006) (cited by Lööf, 2009), only 43% of potential knowledge received by multinationals is effectively used by them. The easiness of transference depends on the level of codification. There should be a tendency for most departments to be closely in touch with the decision centers in the home country due to costs to transfer knowledge and to the need to have information from different stages of the productive process. This may explain the great level of centrality of R&D expenditures until today.

When the foreign R&D is associated with the need of business units to absorb externally produced knowledge, the subsidiaries have to be able to understand problems posed by other R&D labs and to apply the solutions proposed. Knowledge may also be specific to the problems of the unit where it is developed.

Therefore, even in the cases where there is absorptive capacity and knowledge transferability, the transference of knowledge across units requires the possession of complementary assets. And even having complementary assets, some failures in the information transmission channels may cause problems in the management of networks (Papanastassiou and Pearce, 1995). As a conclusion, the closer the knowledge produced is to application, the greater the level of specificity of the search process, and therefore the harder it should be to transfer. Autonomy and specificities of the subsidiaries can reduce their capability to contribute with own knowledge to the network as well as can generate problems to the subsidiary access to the available knowledge in the network (Zanfei, 2000). Both would represent additional obstacles to the technology transfer internally. In this sense, there is a trade-off in the decentralized model. The shift towards independent decision centers created further obstacles for the transference of the knowledge produced as well (Rocha and Urraca-Ruiz, 2006).

Finally, the capacity to transfer knowledge will depend on the degree of knowledge codification. The knowledge should be more tacit the greater its proximity to direct application in production processes. The duplication of technological competences overseas may be a reflection of the inability to transfer applied knowledge across subsidiaries (Coombs, 1996). In this case, the undertaking of foreign R&D will not be related to technology transfer due to the local character of knowledge.

2.2. Location of competences in the "technological frontier"

Capture of competences is a strategy to respond to the challenges of world *technological* and *market heterogeneity* (Filippaios, et. al. 2009). Technological heterogeneity is referred to the different learning potentials that emerge from each National/Regional Innovation Systems. The strategy of capture in this case is to establish overseas labs to develop pre-competitive research, monitoring and learning by interacting with local centers of excellence (leader firms, research institutes, etc.). This kind of strategy pushes a pattern of potential technology transfer inside the triad countries (United States, Europe and Japan), given that, in those countries, the location of competences in the *technological frontier* is more probable.

However, this kind of strategy can also be directed to developing countries if they develop centers of excellence around specific technologies or technological niches. For example, according to the *Bureau of Economic Analysis of United States,* the share of R&D from American subsidiaries in developing countries jumped from 5.2% to 21.4% between 1989 and 2008 and most of these investments were destined to Asia (Cunha and Miranda, 2011). In Brazil, the Technological Park of Rio de Janeiro attracted the most important technological leaders of the oil and gas supply industry to make important R&D investments to resolve the technological challenges of exploring the “pre-sal” (Urraca-Ruiz and Rocha, 2011; Rocha and Urraca-Ruiz, 2011).

Market heterogeneity induces to the second type of competences capture. This capture is made by the creation of labs whose objective is to operationalize the own technology in collaboration with local agents to adapt own products to local needs or market specificities (Filippaios, et. al. 2009). Sometimes, multinationals can establish also *support laboratories overseas* to transfer the internal technology and enlarge the efficiency of subsidiaries in assimilating and operationalizing them in new products or products oriented to host markets (*outward technology transfer*) (ibidem, 2009). As this kind of overseas technology transfer does not require local-host technological advantages, it is most probable to occur in developing countries.

2.3. External networks

One of the most outstanding characteristics of the new organization model is that GC develop external networks with non-related firms and institutions and this kind of relationships involve subsidiaries as much as headquarters (Zanfei, 2000). External networks in host countries is result of the local diversity as sources of competences and complementary assets that, in many occasions, can be applied and exploited by different units in the network or at global scale. The asset complementarity can be related to technologies and products. Complementarity of technological assets takes a more strategic character and it is associated to valuable *context-specific and non-codified knowledge* capture and encompasses cooperative arrangements with local-host agents (firms or institutions). Complementarity assets referred to products results in contractual arrangements (for example subcontracting or outsourcing with users, suppliers, clients; employing local scientist and engineers or labor force; etc.) that can be used as a source of new ideas to be adapted to local products and markets. Some empirical studies conclude that external networks can influence the innovative performance of overseas subsidiaries; R&D agreements used to be non-hierarchical with local agents in least developing countries; and collaborative arrangements used to occur in knowledge intensive industries and mostly when the asymmetries between the home and host countries are low (Zanfei, 2000).

3. Global corporations and environmental technologies

To measure national technological competences, this paper uses patent data filed at the European Patent Office (EPO) between 1980 and 2010. Patents are largely used by the literature to analyze technological competences at the national level because they represent the results of formal or informal innovation efforts (Griliches, 1990; Brockhoff, 1992). They provide detailed data in a regular and long time series that may be grouped by firm, country, geographic location or technical field. However, there are also some limitations of patent data as a measure of national technological competences. Firstly, patents underestimate the contribution or closeness of scientific bases to the creation of technical bases because of ‘the lack of engineering capabilities to embody scientific results in profitable products’ (Brusoni and

Geuna, 2003). Conversely, it is possible that a country has strong competences and capabilities in development but is weakly supported by basic knowledge (ibidem). Secondly, some national technological competences can be underestimated when they are built on non-patentable technologies (or bases of knowledge) or on technologies that are not protected by patents (Dernis, et. al. 2000; Rassenfosse, et. al. 2013).

In the environmental field, a large body of literature has been developed using patent data. Some of these works have focus on examining invention and diffusion of instrument for the control of air pollution in carbon plants (Popp, 2006) or to analyse the effects of policies and market factors, such as the increases in pollution abatement expenditure (Brunnermeier and Cohen, 2003) or green certificates schemes in the development of renewable energies technologies in OCDE countries (Johnstone, et.al., 2010). Also it is important to reference the studies analyzing the role of patents in green innovation and technology transfer (Eaton and Kortum, 1996; Lanjouw and Mody, 1996).

The EPO database shows patent protection in Europe, which can overestimate the concentration of technological capture inside Europe and, as a consequence, inside the triad. Nevertheless, the EPO is the most internationalized patent office in the world, because a simple patent is extensible to all Munich Convention member countries, which eliminates any 'domestic effect' as UPSTO (American Patent Office) does (Le Bas and Sierra, 2002; Zeebroeck, et. al. 2006). In addition, fee applications at the EPO are relatively higher, which acts as an economic filter and eliminates patents of low industrial value (Grupp and Schmoch, 1999).

The empirical work was made over selected relevant patent classes with significant global GHG emission abatement potential. For that, it was used the classification in eight environmental technology fields by combining OECD (2009) and the "IPC Green Inventory" of the International Patent System[1] (see table 1).

Table 1. Description of environmental technological groups

	TOPIC	DESCRIPTION
Chapter 1	Energy generation through renewable energy sources	Geothermal, hydroenergy, solar energy, wind energy.
Chapter 2	Combustion technologies with mitigation potencial	Alternative energy production-cycle combined, integrated gasification combined cycle
Chapter 3	Technologies for the production of fuel of non-fossil origin	Biofuels: biodiesel, bioethanol, biogas
Chapter 4	Technologies with potential or indirect contribution to GHG emissions mitigation	Fuel cells
Chapter 5	Energy conservation	Storage of electrical energy, measurement of electric consumption, storage of thermal energy, low energy lighting, thermal building insulation, recovering mechanical energy
Chapter 6	General Environmental Management	Air pollution abatement, Water pollution abatement, Waste Management, Soil Remedetion, Environmental Monitoring
Chapter 7	Emissions Abatement and Fuel Efficiency in Transportation	Technologies specific to propulsion using internal combustion engine: conventional motor vehicles, hybrid vehicle, Technologies specific to propulsion using electric motor; Technologies specific to hybrid propulsion, Fuel efficiency-improving vehicle design
Chapter 8	Agriculture/Forestry	Forestry techniques, alternative irrigation techniques, pesticide alternatives, soil improvement

Source: The authors' elaboration.

[1] The IPC Green Inventory collects environmental sound technology as listed by the United Nations Framework Convention on Climate Change (UNFCCC).

As a whole, it was collected 50,087 patents. The distribution of patents across chapters reveals that most environmental technological efforts corresponds to Emission Transport (21, 8%), Agro-forestry (34, 4%) and Environment (37, 3%) (see table 2). This result is close related with three facts. Firstly, the dominant energetic paradigm, still based in oil and gas and hydroelectric, puts Renewable energies, Non-fossil fuel and Combustion technologies in second place. Secondly, Kyoto Agreement gave major attention to environmental efforts to reduce CO_2 emissions, which reflects positively in Environment and Emission transports technologies. Thirdly, environmental technologies are horizontal to a set of industries. As industries differ in the propensity to patent, the environmental technologies with more level of patents are closely associated with higher propensities to patent. That is the case of Machinery, Motors and Pumps, Automotive and Automobile industry in Environmental and Emission Transport and Chemicals and Pharmaceuticals in Agro-industry.

Table 2. Patent distribution classified by environmental technology and by type of applicant (%)

	I.Renewable energy	II. Combustion technologies	III. Non fosil fuel	IV. GHG Mitigation	V. Energy conservation	VI Environment	VII Emission transport	VIII. Agro-forestry	Total Patents by applicant nature	Weight over total
National Enterprises	4,1	0,2	0,9	0,7	2,6	53,6	9,0	28,9	14945	-
National Enterprises Cooperation	3,6	0,0	1,8	0,0	2,1	55,3	9,4	27,7	329	-
University-Industry Cooperation	1,6	0,0	4,9	0,0	3,3	29,3	4,1	56,9	123	-
Global Corporations	1,2	0,4	0,6	0,6	1,9	25,6	31,8	37,9	27936	-
Global Corporations Cooperation	1,3	0,1	1,3	0,5	1,7	35,2	29,2	30,5	753	-
Universities and Research Centers	1,9	0,1	1,6	1,4	2,0	28,9	8,4	55,8	1946	-
Individuals	10,2	0,1	0,4	0,1	1,8	60,5	6,5	20,4	4055	-
Weight over total	*2,9*	*0,3*	*0,7*	*0,6*	*2,1*	*37,3*	*21,8*	*34,4*	*50087*	-
National Enterprises	43,3	17,9	35,1	32,7	37,1	42,9	12,4	25,1	-	*29,8*
National Enterprises Cooperation	0,8	0,0	1,6	0,0	0,7	1,0	0,3	0,5	-	*0,7*
University-Industry Cooperation	0,1	0,0	1,6	0,0	0,4	0,2	0,0	0,4	-	*0,2*
Global Corporations	23,5	77,9	46,0	55,3	50,0	38,3	81,4	61,5	-	*55,8*
Global Corporations Cooperation	0,7	0,7	2,7	1,3	1,3	1,4	2,0	1,3	-	*1,5*
Universities and Research Centers	2,6	0,7	8,8	9,0	3,7	3,0	1,5	6,3	-	*3,9*
Individuals	29,0	2,8	4,1	1,7	6,9	13,2	2,4	4,8	-	*8,1*
Total Patents by chapter	1433	145	365	300	1040	18658	10931	17215	-	*50087*

Source: The authors' elaboration from EPO Espace bulletin, 1978-2010.

At the same time, identified for each patent, the nature of the applicant, this is, if the patent had one individual applicant (differentiating between National Enterprises, Global corporations, Universities-Research Centers and Individuals); or if the patent had more than one applicant in cooperation (differentiating between National Enterprises Cooperation, University-Industry Cooperation and Global Corporations Cooperation, which grouped cooperation with other multinationals, with National Enterprises and with Universities-Research Centers). All the patents and their applicants were checked one by one. Firms with more than 10 patents that recognized in their web-sites their global activity were considered as Global Corporation. It was not considered as cooperation the patents that have more than one applicant but they are related by ownership.

As expected, most of the technological activity expressed by patents is concentrated in firms. Global corporation contribution to environmental technologies advances is quite significant in Emission Transport, Combustion Technologies, Agro-forestry, GHG mitigation, Energy Conservation and Non-fossil fuels. In all this cases, their contribution is superior to the National Enterprises contribution. It is worth to mention that the related industries to these technologies are also the most internationalized in production (Chemicals, Pharmaceuticals and Health Care or Automobile), even not all of them are the most internationalized in R&D (Cantwell, 1995). Although the cooperation activity is very low, the comparison between National and Global cooperation enterprises shows also the relevant role of multinationals. In Environment, Emission Transport and Agro-forestry, GHC Mitigation, and Combustion technologies the contribution of GC cooperation is superior to the sum of National Enterprises Cooperation plus University-industry cooperation. Finally, Universities and Research Centers contribute marginally with some concentrated efforts in GHG mitigation and Non-fossil fuels.

4. Capture of technological competences

Potential disembodied technology transfer across the world will be analyzed from a set of indicators. Firstly, it will be generated two matrixes. One is to establish the connections between the inventors and the applicants' residence and other to reflect the potential of technology transfer between inventors with different residence that participate in the same research team. Each matrix will be elaborated with all patents and with patents filed by multinationals (individually and in-cooperation).

Matrix I relates applicant residence (in *i-lines*) and inventor residence (in *j-columns*). Each x_{ij} in matrix I describe the number of patents filed by applicants that reside in the country/area in the line with inventors that reside in the country/area in the column. Restricting the applicants to Global Corporations (and its cooperation), this matrix express the international capture of technological competences by multinationals for all the x_{ij} where $i \neq j$. Table 3 presents the proportion of each x_{ij} represented by multinationals over the total for all the applicants. Column (1) shows the relative importance of multinationals over other applicants by residence region. Some interesting observations can to be noticed. First, total in columns represents the share of patents filed by multinationals according to residence-country applicant.

The contribution of multinationals to environmental technologies advance by country of GC residence is quite high in Japan (81, 2%) followed by Germany (68, 0%) and Switzerland (64, 4%). Second, the matrix confirms that capture of competence is actually concentrated in the triad, this is, among European leaders, United States and Japan and their areas of influence (shaded part). Third, despite of the activity outside the triad is quite low, multinationals conduct 100% and quite high shares of world capture in developing and emergent countries. These are the cases of Germany in Brazil, Oceania, Africa and Asia; France with Brazil, Oceania and Asia; Switzerland with Brazil and Latin America; or Japan with Brazil, Canada and Asia. Capture of external competences by American multinationals is not especially relevant. They seem to focus their capture inside the triad.

Table 3. The world capture of technological competences by multinationals (% over total)

	OCE	LA	BR	CA	US	DE	FR	GB	CH	EU-C	EU-N	EU-P	EU-E	NME	JP	CN	IN	AS	ZA	AF	(1)
OCE	12,0				6,7			10,0											1,7		10,6
LA*	50,0				3,7	26,7		71,0							50,0						16,4
BR			20,5				50,0									100,0					20,5
CA				12,1	38,7	33,3		50,0				100,0			100,0						13,9
US	62,3	56,0	58,3	53,0	52,6	81,4	85,4	74,2	68,1	84,8	74,1	63,9	32,5	7,0	68,8	30,0	61,3	47,6	50,0		54,9
DE	86,4	66,7	95,7	60,8	92,9	67,4	93,0	92,1	63,8	73,9	85,4	85,3	58,8	60,0	97,8	87,0	100,0	97,0	81,3	100,0	68,0
FR	90,9	50,0	83,3	47,1	87,0	81,2	47,5	92,2	63,2	37,2	76,9	57,6	16,7		92,9	80,0		55,6		42,9	51,7
GB	36,8	75,0	50,0	27,3	75,5	44,2	71,4	43,9	77,5	79,2	50,0	40,0	9,1		83,3	83,3	80,0	50,0			46,8
CH	88,9	100,0	100,0	41,7	86,4	82,1	69,5	84,5	63,7	47,3	75,0	40,0	45,5	33,3	81,3	50,0	75,0	3			64,4
EU-C	100,0	63,6			77,0	47,1	50,4	88,7	53,4	24,8	58,6	20,0	8,3	28,6	66,7	66,7	77,8		100,0	100,0	36,5
EU-N	40,0			14,3	57,1	53,1	50,0	58,0	50,0	42,9	33,6	100,0	15,4		100,0	100,0		100,0			35,3
EU-P				42,9	18,9	37,1	30,0	15,4	52,9	25,0	10,0	21,6			55,2			12,5	100,0		20,9
EU-E						46,2							1,9								1,8
NME						50,0								4,5	33,3						4,9
JP			100,0	100,0	70,3	97,7	83,3	81,5	91,7	66,7	57,1	57,1	20,0	100,0	81,3		100,0	42,9			81,2
CN					8,3	33,3										2,7					2,3
IN					33,3												7,2				8,2
AS	25,0					37,5									16,7			73			17,1
ZA					100,0			100,0											20,0		20,0
AF																					0,0
Total	135	42	112	168	6268	10031	1786	1579	1162	931	774	580	44	19	7468	49	41	174	24	8	57,3

(*) Just subsidiaries of Pfizer and in Panama.

OCE, Oceania, Australia and New Zeeland; LA Other Latin American; BR Brazil; CA Canada; US United States; DE Germany; FR France; GB United Kingdom; CH Switzerland; EU-C Benelux and Austria; EU-N Finland, Norway, Denmark, Sweden; EU-P Italy, Spain, Portugal, Greece and Ireland; EU-E East Europe; NME, Near and Middle East; JP Japan; CN China; AS Other Asian; ZA South Africa; AF Other African.

* There is no Latin American GC. These are patent by Pfizer subsidiaries that reside in United Kingdom and Panama and applied jointly.

Source: The author's elaboration from EPO Espace Bulletin, 1978-2010.

Table 4. Transfer of non incorporated technology in environmental technologies in the world (% over total)

	OCE	LA	BR	CA	US	DE	FR	GB	CH	EU-C	EU-N	EU-P	EU-E	NME	JP	CN	IN	AS	ZA	AF	(1)	(2)
OCE				20,0	44,7	70,0	40,0	43,8	100,0	33,3	50,0	87,5				20,0		60,0			22,7	48,8
LA					55,0	79,2	57,1	100,0	100,0	50,0			100,0			100,0					33,1	62,3
BR				100,0	94,3	94,4	93,8	100,0	100,0	100,0		100,0			100,0	100,0		100,0			73,2	95,0
CA	20,0		100,0		53,9	50,0	50,0	75,0	66,7	33,3	28,6	100,0			100,0			12,5			24,8	52,3
US	44,7	55,0	94,3	53,9		87,1	85,0	67,0	78,6	76,2	62,7	56,0	12,5	9,8	73,0	28,6	54,8	44,0	88,9		54,3	69,9
DE	70,0	79,2	94,4	50,0	87,1		90,9	86,0	84,3	74,5	59,4	81,2	69,7	50,0	97,6	61,1	100,0	94,2	90,9	80,0	67,6	84,4
FR	40,0	57,1	93,8	50,0	85,0	90,9		85,2	87,1	56,7	46,7	65,9	14,3		97,8	83,3	20,0	57,1		42,9	52,4	79,8
GB	43,8	100,0	100,0	75,0	67,0	86,0	85,2		89,5	75,9	48,6	47,4	25,0		83,3	33,3	100,0	66,7	40,0	100,0	52,9	71,3
CH	100,0	100,0	100,0	66,7	78,6	84,3	87,1	89,5		64,5	58,3	61,9	50,0	100,0	60,0		100,0	60,0			62,2	80,8
EU-C	33,3	50,0	100,0	33,3	76,2	74,5	56,7	75,9	64,5		52,6	40,7	80,0		66,7	100,0	25,0	50,0	100,0	100,0	36,7	69,7
EU-N	50,0			28,6	62,7	59,4	46,7	48,6	58,3	52,6		40,0	25,0		100,0	100,0	33,3		100,0		38,5	53,3
EU-P	87,5		100,0	100,0	56,0	81,2	65,9	47,4	61,9	40,7	40,0		50,0		71,4		100,0	100,0			27,1	62,8
EU-E		100,0			12,5	69,7	14,3	25,0	50,0	80,0	25,0	50,0									9,3	38,5
NME					9,8	50,0			100,0						50,0						5,7	10,3
JP			100,0	100,0	73,0	97,6	97,8	83,3	60,0	66,7	100,0	71,4		50,0			100,0	66,7			81,3	84,9
CN	20,0	100,0	100,0		28,6	61,1	83,3	33,3		100,0	100,0						100,0	66,7			27,5	45,4
IN					54,8	100,0	20,0	100,0	100,0	25,0	33,3	100,0			100,0	100,0			100,0		32,8	60,3
AS	60,0		100,0	12,5	44,0	94,2	57,1	66,7	60,0	50,0		100,0			66,7	66,7					31,1	66,5
ZA					88,9	90,9		40,0		100,0	100,0						100,0				22,6	78,8
AF						80,0	42,9	100,0		100,0											40,0	60,0

(*) Just subsidiaries of Pfizer and in Panama.

OCE, Oceania, Australia and New Zeeland; LA Other Latin American; BR Brazil; CA Canada; US United States; DE Germany; FR France; GB United Kingdom; CH Switzerland; EU-C Benelux and Austria; EU-N Finland, Norway, Denmark, Sweden; EU-P Italy, Spain, Portugal, Greece and Ireland; EU-E East Europe; NME, Near and Middle East; JP Japan; CN China; AS Other Asian; ZA South Africa; AF Other African. (1) Share of patents is filed by multinationals according to inventor's residence-country; (2) Share of patents filed by multinationals that used foreign inventors in their research teams according to inventor's residence-country. Source: The author's elaboration from EPO Espace Bulletin, 1978-2010.

Matrix II reports the number of patents that relate inventor residence (in *i-lines*) with others inventor residence (in *j-columns*) that work in the same research team. Each x_{ij} in matrix II describes the number of patents with inventors that reside in both the countries/areas expressed in the corresponding line and column. Restricting the applicants to Global Corporations (and its cooperation), matrix II shows the transfer of knowledge that crosses borders through the shared experience of research in a team that worked for a multinational. So, this kind of technology transfer is characterized by having a non-incorporated character. This is a symmetric matrix with zeros in the diagonal, because it does not consider the number of patents with only one residence-country in the inventors' team.

Similarly, table 4 presents the proportion of each x_{ij} represented by multinationals over the all applicants. Column (1) shows the share of patents with inventors resident in the corresponding line-country filed by multinationals. It gives the quote of national/regional competences taken by multinationals. Highest rates of captured knowledge are registered by Japan (81%), Brazil (73%), Germany (67%), and Switzerland (62%). This is not a surprising finding for leader countries, given that most of multinationals residence in these countries, but it is for Brazil. Comparing this result with the obtained in table 3, it seems clear that the capture of competences by multinationals in Brazil stimulates the transfer of knowledge across different countries due to Brazilian inventors participate of high internationalized research teams.

Column (2) shows the propensity to use foreign inventors by multinationals by inventor's residence-country. Most of cases this propensity is superior to 50%, this is, at least 50 per cent of patents that use the inventor's country-residence are filed by multinationals. The highest propensities are registered by Brazil (95%), Japan and Germany (84%), and Switzerland and France (around 80%).

Another interesting observation is that technology transfer is not as concentrated in the triad as the technological capture. Nevertheless, as in table 3, African and Near-Middle-East countries still have a null or marginal relevance. It calls the attention the elevated number of cases that indicate 100% of total use in countries/areas outside the triad, which is more frequent than inside the triad. As expected, that shows the cases in which the use of inventors outside the triad is conducted by multinationals. By contrast, the share of resident inventors in the triad used by multinationals is relatively lower in comparison with other agents, given that national enterprises and research centers also uses local competences (inventors) hosted in their own countries. A second set of indicators for different levels of technology transfer inspired in Zander (1998), Guellec, et. al. (2001) and Picci and Savorelli (2012), can be developed from the matrixes. These are:

- *Local-for-local*, which indicates the part of national competences that are taken by applicants that reside in the country. It is calculated as $LL_j = \frac{\sum_{i=1}^{n} P_{ij}}{N_j} \; \{\forall i = j\}$, where P_{ij} is the number of patens by applicants that resides in *i-country* and takes inventors from *j-country*; n is the number of geographical areas considered where the applicants and inventor resides; and N_j is the total number of patent applications by country of inventor residence.
- *Local-for-Global* that indicates the extent to which a country is captured by non-resident agents. It measures the part of national competences that are taken by applicants that are not residing in the country. It is calculated as $LG_j = \frac{\sum_{i=1}^{n} P_{ij}}{N_j} \; \{\forall i \neq j\}$ following the same nomenclature above.

- *Global-for-local*, that measures the geographic dispersion of the capture, this is, the share of patens by *i-country* (applicant residence) that takes inventors from *j-country* (inventor country), being i and j different countries. Formally, it can be expressed by: $GL_i \frac{\sum_{j=1}^{n} P_{i,j}}{N_i} \{\forall i \neq j\}$, where N_i is the total number of patents applications by country of applicant residence.

Results are reported in table 5. Due to geographical proximity, it should be observed a higher propensity to take national competences internally expressed by relative high local-for-local indicator values (near to 100). This hypothesis can be tested for triad countries, but also for Canada (CA), Oceania (OCE), Near and Middle East (NME) and Other Asian countries (AS). Nevertheless, this expected observation in not confirmed in developing countries, especially in Brazil (BR), Other Latin American (LA), China (CN), South Africa (ZN) and Other African (AF). By opposite, technological competences of those countries are captured by non-resident agents, especially multinationals, which are expressed by high local-for-global indicator values. There are two reasons to explain that observation. Firstly, it is because domestic firms are low R&D intensive. Secondly, because international capture of technological competences is a process leaded by multinationals and, multinationals that reside in these countries/areas do not make R&D effort relevant enough to capture their national technological competences. The most representative examples are Brazil and South Africa. In Brazil, 76.5% of the patents with Brazilian inventors are applied by non-resident agents and 69.3% are non-resident multinationals in Brazil. The same tendency is observed in China, but the external capture by multinationals is quite smaller. About 60% of the patents with Chinese inventors are deposited by non-resident applicants in China, but only 27.5% is the part captured by non-resident multinationals.

Finally, global-for-local indicator measures the capture of overseas technological competences of a country through their resident applicants. In some extent, this is a kind of technological internationalization indicator for a country or a region. Observing the data, it is quite clear the identification of two different patterns. On one side, the leader countries (triad and their influential areas in the developed world) show very dispersed levels of overseas capture considering all applicants, but in most of them, the global-for-local indicator calculated only considering multinational applicants are quite close. That observation means that the overseas technological capture is mostly leaded by multinationals in leader countries. The lower proportion in this group is registered by Europe-North (EU-N) with 51% and the highest Germany (DE) with 86.6%.

Table 5. Levels of internal and overseas technological capture

	ALL APPLICANTS			GC APPLICANTS				N. PATENS by	
	Local for local	Local for Global	Global for local (A)	Local for local	Local for Global	Global for local (B)	(B)/(A)	Applicant's country (N_i)	Inventor's country (Nj)
OCE	79,8	23,4	18,7	9,6	13,9	0,6	2,9	545	595
LA[a]	48,8	62,2	75,7	0,0	36,2	16,4	21,6	177	127
BR	25,5	76,5	7,7	5,2	69,3	5,1	66,7	39	153

CA	64,5	42,3	20,6	7,8	20,2	7,6	36,7	476	678
US	83,6	20,2	18,2	44,0	13,3	12,8	70,0	10665	11546
DE	92,7	9,0	13,7	62,4	6,3	11,9	86,6	14377	14847
FR	82,8	20,4	19,3	39,3	15,1	15,0	77,4	3204	3409
GB	74,0	34,5	23,4	32,5	27,2	15,2	64,8	2512	2970
CH	85,9	19,6	45,6	54,7	12,1	35,4	77,6	2084	1869
EU-C	74,8	29,0	40,6	18,6	20,2	25,0	61,4	2685	2540
EU-N	87,2	15,0	14,7	29,3	10,1	7,5	51,1	1902	2010
EU-P	84,8	17,3	28,3	18,3	9,6	6,3	22,2	2325	2139
EU-E	66,2	38,4	11,4	1,3	9,7	1,8	15,8	334	474
NME	80,3	27,8	21,0	3,6	3,3	1,4	6,7	286	335
JP	97,2	4,0	2,6	79,0	3,2	2,0	76,6	8999	9188
CN	42,1	60,1	38,6	1,1	27,5	2,3	5,9	88	178
IN	54,3	57,5	12,3	3,9	36,2	2,7	22,2	73	127
AS	73,6	28,2	12,5	13,0	18,0	1,1	8,9	448	560
ZA	4,7	100,0	60,0	0,9	22,6	40,0	66,7	5	106
AF	45,0	70,0	50,0	0,0	40,0	-	-	14	20

(a): There is no Latin American GC. These are patent by Pfizer subsidiaries that reside in United Kingdom and Panama and applied jointly. Source: The author's elaboration from EPO Espace Bulletin, 1978-2010.

By contrast, the role of multinationals in catching-up, developing and emergent country is much lower. The contribution of GC has the lowest values in Oceania (2.9%) and China (5.9%) and only a little higher in Europe-peripheral, India (22.2%) and Europe-East (15.8%). Only two countries look to be the outsiders: Brazil (BR) and South Africa (ZA). The case of South Africa can be unconsidered given the scarce number of patents deposited by applicants that resides in this country (only 5). Brazil has also few patents deposited by residents to establish a representative strategy global-for-local. There are only three cases of overseas capture. Two of them came from foreign multinationals with subsidiaries in Brazil (*Montanto do Brasil* and *Bayer do Brazil*). The third one came from a national research center (EMBRAPA).

5. Concluding remarks

This paper purpose is to explore the role of multinational to capture of overseas competences in environmental technologies. Theoretical aspects indicate that not always the capture of competences means international technology transfer given the limits of knowledge to flow even inside the internal networks.

To differentiate technological competence capture and technology transfer, the empirical analysis uses two different indicators from patent statistics. Indicators for world technological competences capture were measured from a matrix that relates the residence-country of applicant agent (the capturer) to the residence-country of the inventor (the captured). World technology transfer indicators were built from a matrix that relates residence-countries between inventors that work in the same research teams.

Technology transfer is more dispersed but still almost-null in Africa and in Near-Middle East. The participation of foreign inventors is more usual in multinationals. That observation points out that multinationals guide the world technology transfer in this kind of technologies. The concentration of technological capture inside the triad is confirmed when it is conducted by multinationals. This is also observed in local-for-local indicators for triad countries and their influential areas. Nevertheless, emergent countries like Brazil, China or South Africa are more characterized by to be captured than to be capturers of technological competences inside the triad. This can be explained by a scarce numbers of domestic multinationals, a low R&D intensity by domestic agents and a low level of R&D internationalization outwards.

The conclusions of this work contribute with empirical support on the theory of technological internationalization. However, some questions can be still better explored about the relations between the capture and the technological specialization of each country (or area) by environmental technology or the role of external networks. Both must be object of study in future works.

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