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Do Industry 4.0 policies and New Technologies provide an incentive to re-shore foreign activities?
An empirical study on European manufacturing companies

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Abstract (English Version)

Manufacturing firms all over the world are starting to take advantage of the benefits of the Fourth Industrial Revolution, consisting in the diffusion of new technologies of production and production management. These techniques might disrupt the productive systems in all the manufacturing sector. In this context, some governments are launching policies aimed at making their country more attractive, with public investment programs, called, "Industry 4.0"

This study explores the possibility of existence of a correlation between the new technologies diffusion and the Relocation of Second Degree (RSD).

RSDs are transfers in foreign countries of previously offshored divisions, by manufacturing firms. A RSD can be a Relocation in a Third Country (RTC) or a Relocation in the Home Country (RHC).

The first part of this dissertation consists in a literature review, based on three topics. The first, analyses the relocations, with emphasis on the RSD. Secondly the new technologies of the Fourth Industrial Revolution and the "Industry 4.0" initiatives are presented, including technical concepts and managerial implication. The third section explores the links between the adoption of new technologies and the choices for the RSD.

In the following chapters data are presented, first as descriptive statistics, then with an econometric model, in order to examine the relationships between new technologies and the choice between RHC and RTC.

The results do not establish a direct correlation between new technologies and RSD, given the used metrics. It is possible to verify how the new technologies affect the decisions of RHC or RTC, when these are linked with other factors usually driving the decision towards one of the two options. In fact, the strategic asset seeking driver, joint with the new technologies' adoption prompt the companies into RHC. Conversely, the Industry 4.0 initiatives, joint with the cost reduction strategies are an enhancer for the decision of RTC. This result suggests a deeper investigation about the role of new technologies and the national investments in Industry 4.0 in fostering RSDs.

Keywords: Relocation; Reshoring; Offshoring; Industry 4.0; Fourth Industrial Revolution; Technology; Productive System; Manufacturing Sector; Country-specific advantages.

Abstract (Italian Version)

Le aziende manifatturiere, in tutto il mondo stanno iniziando a godere dei benefici della Quarta Rivoluzione Industriale, che consiste nella diffusione di nuove tecnologie di produzione e di gestione della produzione. Tali tecniche, potrebbero rivoluzionare i sistemi produttivi di tutto il settore manifatturiero. In questo contesto, alcuni governi stanno lanciando delle iniziative volte a rendere più attrattivo il proprio paese, con programmi di investimenti pubblici chiamati, generalmente, "Industria 4.0".

Questo studio esplora la possibilità che esista una correlazione tra la diffusione di nuove tecnologie e le Rilocazioni di Secondo Livello (RSL).

Le RSL sono dei trasferimenti in paesi esteri di divisioni precedentemente delocalizzate da parte di aziende manifatturiere. Una RSL può essere una Rilocazione verso un Terzo Paese (RTP) oppure una Rilocazione verso il Paese d'Origine (RPO).

La prima parte del lavoro consiste in una revisione della letteratura, basata su tre argomenti. Il primo studia le delocalizzazioni, con enfasi sulle RSL. Il secondo è la presentazione delle nuove tecnologie della Quarta Rivoluzione Industriale e "Industria 4.0", comprendente nozioni tecniche e implicazioni manageriali. La terza sezione esplora i legami tra le adozioni di nuove tecnologie e le possibili scelte per le RSL.

Nei capitoli successivi vengono presentati i dati, prima come statistiche descrittive e poi con un modello econometrico, per esaminare le relazioni tra nuove tecnologie e la distinzione tra RTP e RPO. I risultati non stabiliscono una correlazione diretta tra le nuove tecnologie e rilocazioni, stanti le metriche utilizzate. Si può comunque constatare come le nuove tecnologie influenzino le decisioni di RTP o RPO, quando queste vengono collegate ad altri fattori che normalmente guidano la decisione verso una delle due possibilità. La ricerca di asset strategici, infatti, se collegata all'adozione di nuove tecnologie è un fattore che orienta la decisione verso una RPO. Al contrario, un'iniziativa di Industria 4.0, se unita alla riduzione di costi, aumenta la probabilità di una RTP. Questo suggerisce un'indagine approfondita, con altre metriche sull'uso di nuove tecnologie e gli investimenti governativi in Industria 4.0.

Parole Chiave: Rilocazione; *Reshoring;* Delocalizzazione; Industria 4.0; Quarta Rivoluzione Industriale; Tecnologia; Sistema Produttivo; Settore Manifatturiero; Vantaggio specifico per paese.

Executive Summary

This dissertation studies the effects on the relocations of second degree (RSD) of the new technologies, in particular, the ones related to the Fourth Industrial Revolution (FIR) and the innovation potential given by the national initiative Industry 4.0.

Thanks to their potential, the new technologies can disrupt the traditional schemes of the productive system and, thus, reshape the location choices of the Multinational Enterprises (MNEs). The aim of the dissertation is to establish an eventual correlation effect between the adoption at firm level of the new technologies and the presence of an initiative Industry 4.0 to the choice in relocating a second time the productive activity previously offshored.

The analysis begins in *chapter 1* a literature review of the two main topics. The basic concept behind the organization of the chapter is the analysis of the two matters first in a separate way and then, in the third section, to find eventual points of contact.

In the first section the topic is the reshoring. First, a theoretical conceptualization is given to the phenomenon of reshoring, starting from the definition of offshoring and coming to the final definition of RSD, with the distinction in relocation to the home country (RHC) and relocation to third country (RTC). Secondly, there is an analysis of the main trends in the research on this topic, by trying to find measures for the magnitude of the phenomenon, the principal origins and the most desired targets. The third paragraph regards the possible motivations, starting from the ones obtained with anecdotal investigation, coming to the more organized frameworks, aiming to categorize the specific reasons for reshoring into macro-categories.

The second section of the literature review analyzes the new technologies. The first paragraph describes the literature regarding the FIR and the way in which countries are related to these innovations, so with the Industry 4.0 national initiatives. The second paragraph consist in a description of the new technologies and the relative specific devices. Among the technologies, large importance is given to the Cyber-Physical Systems, the Internet of Things and Additive Manufacturing. The final paragraph of this section regards the managerial implications that can emerge from the implementation by the firms of the new technologies, with respect of the reshaping of the value creation chain.

The third section of the literature review consist in the examination of the extant works that describe the possible interactions between the adoption of the new technologies and the possible location choices of the firms. Large importance will be given to the concept of the effect on the Global Value Chain (GVC) brought by the adoption of the new technologies, studied singularly. The adoption is discussed in relation with the OLI eclectic paradigm of Dunning (2001). Finally, the work of Müller, Dotzauer, and Voigt (2017) is mentioned, since it is the first that attempts to summarize the effects on the relocations of the stream of the Industry 4.0 technologies and initiatives as a whole. At this point, I formulated my research question, investigating if the influence of the new technologies has an effect of the choice of RTC or RHC.

Once the terms are conceptualized and the possible explanations of the phenomena are given, in *chapter 2*, some descriptive statistics are exhibited. The first dimension of analysis is the description of the magnitude of the trends in the RSD, studying the possible events that may have influenced the trends, such as the EU expansion in 2004 or the global recession began in 2008. In this section are presented also the most frequent country of origin and destination for the RSD, distinguished in RHC and RTC. The dataset for is represented by a total of 535 relocation operation extracted by the European Restructuring Monitor (ERM). The second section contains the statistics about the diffusion of the new technologies. The first paragraph studies the national initiatives for Industry 4.0, their diffusion by year of adoption, the funding scheme and, where possible, also the effective spending by the government. Then the diffusion of the technologies at firm level is analyzed, by using the metrics of the patent application for each firm. The patents considered as inherent to the FIR are extracted by the report "Patents and Fourth Industrial Revolution" (EPO 2017).

In *Chapter 3*, the core of the work is presented. The dissertation in fact, presents a regression model aimed at putting in a direct relationship the variables measuring the level of adoption of the new technologies and the presence of an Industry 4.0 initiative, with the choice between a RTC and a RHC. The database is composed by 535 relocations, extracted by the ERM. For each of them, are recorded data about the firm, the year in which the RSD has been carried out, and data regarding the home, the first and the second host countries.

A general presentation of the model is provided initially, followed by a thorough displaying of the variables involved. First, is introduced the dependent variable, a binary variable distinguishing the choice of a RHC over a RTC. Subsequently, the explanatory variables are introduced, measuring the differential in the countries, according to the three determinants, *market-seeking, strategic asset-seeking* and *efficiency-seeking* theorized by Dunning (1993). The regression contains also a set of control variables, checking the presence in the eastern Europe, the cultural distance, the size and the output of the firm.

Two logit regressions are modelled: the first controlling the differential between home country and first host country; the second is based on the differential between second and first host country. All the regressions are run a second time to a subset of firms headquartered in the EU.

In the *Chapter 4*, a discussion of the result is provided. The results confirm the findings of Barbieri et al. (2018), stating that the firms that are pursuing the market seeking and asset seeking advantages are mainly oriented to RHC, while the firms pursuing efficiency enhancing, namely a reduction of the total costs, are mainly oriented to the RTC. Furthermore, some interesting conclusion may be drawn given the influence of the crisis. In fact, the crisis proved to be an enhancing factor for the firms opting for a RHC. Looking at the location of the firms, it possible to highlight a correlation between the firms located in the eastern Europe and the choice of RTC, and they result also to choose as second host country another country of the eastern Europe.

For what concerns the variable related to Industry 4.0 and the patents, in none of the regressions has been possible to retrieve any correlation with the dependent variable. This might be explained by the particular structure of the variables. At this point, I deepened the research by examining the coefficients of the interactions between the technological variables and the location advantages drivers. This analysis provides some interesting results: in particular, the presence in the second host country of an Industry 4.0 policy increases the probability of a RTC, for the firms pursuing cost advantages. On the contrary, the firms pursuing asset seeking advantages, see an enhancement of the probability to undertake a RHC.

Given the quantitative results, it is possible to affirm that the technological variables do not exert an effect on the dependent variable, by themselves. But, those measures influence the different choices for the RSD, when the firm has decided a strategy, whether it is based on the reduction of the costs or to the expansion of the strategic assets.

Given these assumptions, in the last section some indication for a further research are provided. In particular, considering the large number of countries launching a policy in the years 2016 and 2017, an extension of the survey interval is recommended.

Furthermore, I provide some indications regarding the sophistication of the variables. Among these are cited the intensity of the investments of the Industry 4.0 initiative, or, the area of competence of the initiative itself. For what concerns the patents the recommendation is to deepen the research, not only with the patents provided in the EPO, but with a thorough investigation on the devices effectively implemented by the firms analyzed. Furthermore, I present the fact that the variable controlling the total number of patents may not capture perfectly the various level of adoption inside the firms.

Another proposal drawn for a further research is the creation of a control group, in order to obtain a counterfactual analysis. In this way, another aspect of the implementation of the initiative would be explored. In particular, would be inspected the choice for the firms that are in a country where an Industry 4.0 program is in force to remain in a certain country after a relocation of first degree.

In the last chapter, I draw some conclusions, by defining my dissertation as a starting point for a further research in the topic of the relocations of the MNE and the role of the new technologies, whether they are coming from the firm, so for the individual adoption of the devices, or they are coming from a national based policy.

Introduction

The discussion of the firm's relocations is started since the birth of this phenomenon in the 60s and 70s of the 20th century. During this period, many firms of the developed western countries transferred their production abroad, in order to obtain benefits in terms of costs reduction. The increasing of production efficiency, by means of an overall reduction of the production costs in that period, was one of the most desired competitive factors in the years of the industrialization (Ferdows 2009).

In the last years, the stream of relocations of productive activity continued and the academics tried to figure out what are the main trends are. The work of the Fraunhofer Institute for Systems and Innovation Research and the European Restructuring Monitor are the ones which better covered this phenomenon (Armbruster et al. 2005; Kinkel, Lay, and Maloca 2007; Dachs and Cristoph 2014). Moreover, in the very last years, the emergence of the repatriation of the productive activities, has been a phenomenon deeply investigated by academics (Leibl, Morefield, and Pfeiffer 2011; Albertoni et al. 2015; Barbieri et al. 2018).

Among the possible causes of the repatriation of the activities there is the development of new technologies. The diffusion of these technologies is defined in some cases, as Fourth Industrial Revolution. This stream, will have many effect on the production systems all over the world: among the others, it will have a role in reshaping the distribution of the activities of the Multinational Enterprises (Laplume, Petersen, and Pearce 2016; Buonafede et al. 2018). Furthermore, many countries, starting from Germany in 2011 are launching some policies, the "Industry 4.0" programs, aimed at enhancing the productivity at country level, by means of the promotions of new technologies (Lasi et al. 2014a; Irwin 2017).

The aim of this dissertation is the investigation about the possible relation, first from a theoretical point of view than with an econometric model, of the development of the new technologies and the national initiatives with the choices of relocation of the firms.

Chapter 1: Review on the extant literature

1.1 Offshoring and reshoring theory

1.1.1 Offshoring and Back shoring: Conceptualization of the terms

During the recent years, the world is witnessing a particular phenomenon: several industrial Multinational Enterprises (MNE), like Caterpillar[1] and Bosch[2] have announced their intention to return some of their production activities back to their home countries. This phenomenon has been increasingly catching the attention of the academic world as well as it has become widely discussed in the technical literature and in the economic press. A notable example refers to the re-establishment back to the United States of the production line of Apple's Mac products, in 2013 (The Economist, 2013).

The focus of this dissertation will be primarily on the phenomenon of relocation of activities performed by manufacturing firms. This insight, and the specific intention of not inspecting the implications for services, depends on different reasons.

First, the barriers for service relocation are a much lower constraint and the nature of nowadays service activities makes them more blurred than the ones experienced by manufacturing firms (Fratocchi, Barbieri, et al. 2013). Secondly, relocation of activities for services covers a restricted number of countries (Fratocchi, Barbieri, et al., 2013). Third, manufacturing firms have chosen to supply activities abroad to a larger extent, with respect to services ones (Eurostat, 2009). Finally, several western countries, at the government level, are trying to trigger the repatriation of manufacturing activities back from low income countries, with incentives and policies aimed at increasing productivity levels in the home countries (Livesey, 2012).

Since the existence of a reshoring operation implies, among the other conditions, the presence of a previous offshoring decision, defining properly such an operation is a necessary step. In

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[1] Caterpillar repatriated part of its production facility from China to a new facility in Victoria, TX (USA) in 2013.
Source: http://www.greatmanufacturingstories.com/articles/caterpillar-reshoring-to-america.html]
[2] Bosch transferred the production of the packaging systems in April 2016 from Liverpool, UK to Waiblingen, Germany.
[Source: https://reshoring.eurofound.europa.eu/reshoring-cases/bosch-packaging-technology]

this dissertation, I follow Fratocchi et al. (2014 p. 12) in defining offshoring as *"[…] the cross-border (re)location to distant locations of value activities that were once performed within the firm's country of origin, and aims to serve global rather than local demand"*.

Coherently, the extant literature offers confirmation to the fact that a firm's offshoring decision must not be considered only as a non-reversible process (Kinkel et al. 2007). For this reason, several alternative concepts – expressing in different ways the possibilities entailed by the relocation phenomena – can be found in the relevant literature. Traditionally, scholars adopted different concepts and terms to refer to these operations. Among the others, the most used terms are "*international divestment*" (Boddewyn and Torneden 1973), "*de-internationalization*" (Benito and Welch 1997), "*back-shoring*" (Kinkel and Maloca 2009) and "*re-shoring*"(Ellram, Tate, and Petersen 2013). In extant academic contributions, all the cited terms have their own definition; however, each of them lacks in covering one or more aspects of the analysed events.

First, the concept of *international divestment* (Boddewyn and Torneden 1973) encompasses the concepts of the closure of a foreign plant and the subsidiary as a whole, not expressing explicitly the relocation to the home country, the voluntariness of the decision and the difference between in- or out-sourcing (Fratocchi et al. 2014). The second definition, given by Benito and Welch (1997), states that the *de-internationalization* phenomenon consist in a reduction of the engagement in cross-border activities by a company, but not considering the relocation to the home country; furthermore, this definition neglects the possible differences in in- or out-sourcing of the activities (Fratocchi et al. 2014). A third definition refers to the term *back-shoring* and was proposed by Kinkel and Maloca (2009, p. 155); the authors define the adopted terminology as a "re-concentration of part of production from own foreign locations as well as from foreign suppliers to the domestic production site of the company". This regards the in- and out-sourced manufacturing activity abroad, whether it is partial of total, but – as the previous three definitions do – it does not express the voluntariness of the decision. Finally, the definition of *re-shoring* – proposed by Ellram, Tate, and Petersen (2013) – lacks in defining if the transferred activity is in-sourced or out-sourced.

A peculiar example of an offshoring decision could be the relocation of a production activity in a foreign country that is geographically close to the home country. More specifically, in the case in which the foreign country – that is, the host country – belongs to the same region of the home country, such an operation is defined as a *near-shoring*. An example of such an operation could be represented by a French firm that relocates its production activity in an eastern European country (Fratocchi et al. 2014).

Having defined the reshoring phenomenon and its characterising features, a second important point to tackle concerns the definition of the alternative ways through which the relocation can be pursued by the firm. This decision process can be explained leveraging on a four-quadrant matrix. The framework is built upon a two-dimensional analysis: the first dimension is the one that describes the ownership dimension. In particular, it refers to the *make or buy dilemma*: the possibilities given to the firm to insource the production or outsource it to a supplier in a different country. The second dimension regards the spatial dimension: the two possibilities can be national or international. Given the two dimension and the two alternative choices for each one of them, it can be determined which are the four choices for an offshoring decision. The resulting categories are called (Kinkel and Maloca 2009; Gray et al. 2013):

- *national relocation* (national, make) if the firm locates the production in the home country in a firm-owned facility;
- *national outsourcing* (national, buy) if the production is outsourced to a supplier operating in the home country;
- *international relocation* (international, make) if the production is located in a firm-owned facility abroad, to this process usually refers the offshoring definition;
- *international outsourcing* (international, buy) if the firm refers to a supplier in a foreign country.

	Ownership Dimension		
Spatial Dimension		*Internal*	*External*
	National	National Relocation	National Outsourcing
	International	International Relocation	International Outsourcing

Table 1.1 Framework for the relocations, categorized by the spatial and ownership dimensions

Table 1.1 shows the matrix of the relocation initiatives alternatives. The power of this tool comes from its visual immediacy and comprehensiveness in depicting the span of different scenarios eventually undertaken by firms. Nonetheless, as one could understand from the definition of offshoring and the reshoring phenomena presented so far, the outlined model might be applied to both type of decisions – i.e., the original offshoring one and the potentially following reshoring one. This further outline the importance of understanding that the principles guiding both decisions are interlinked and overlapping, and that there exists a strong causal link between the two (as outlined by characteristic *a* in Fratocchi et al. (2013)).

The yet mentioned authors are the main references for the conceptualization of the reshoring term. According to the authors, it reflects "*a voluntary corporate strategy regarding the home-country's partial or total relocation of (in-sourced or out-sourced) production to serve the local, regional or global demands*" (Fratocchi, et al., 2013).

It is important to highlight that not all the reshoring operations are structured in the same way, but there are different possibilities, characterized by the geographical dimension. A key discriminating factor is the target country for the second step of relocation. A firm that relocates its production activities back to its home country is undertaking what is called a back-reshoring operation. Furthermore – analogous as for the *near-shoring* decision when describing the offshoring phenomena – a *near-reshoring* operation can be identified when a firm relocates some activities formerly located in a farer country in the same region of the home country. Differently, a *further off-shoring* happens when a firm relocates its production activity far away from both the first host country and the home country (Fratocchi et al. 2014).

As this research demands for a clearer distinction between the possible different reshoring initiatives, the conceptualization proposed by Barbieri et al. (2018) is helpful to conduct a precise and thorough analysis into the trends and the reasons behind the relocations. In general, a reshoring initiative can be defined as a relocation of second degree (RSD), since it comes necessarily after a first operation of offshoring. The RSD can be divided into two sub-categories, depending on the geographical position of the relocated activity:

- a relocation to home country (RHC), when, after the initial delocalization from country A (i.e., the home country) to country B (i.e., the first host country), the firm, moves the production activity back to country A;

- a relocation to third country (RTC), when, the firm moves the relocated activity from the country B, to a country C (i.e., the second host country), different to the country A.

From now on, and throughout this dissertation, I will mainly refer to a reshoring decision involving the movement back to the home country as "RHC" and to a reshoring decision involving the movement to a third country as "RTC" keeping the notation by Barbieri et al. (2018).

1.1.2 Research trends in reshoring activities

Once a systematic conceptualization of the reshoring phenomenon is defined, a detailed analysis on which are the core topics in the current debate about relocation decision can be performed.

To begin, it is useful to mention that the relocation of production activities is not a recent phenomenon; indeed, it can be considered quite a common fact (Fratocchi et al. 2015). Moreover, the reshoring of value chain activities has interested firms operating in variety of sectors for almost two decades (Kinkel and Maloca 2009).

In particular, the interest of the academics towards the topic of the relocation of the production activities in manufacturing has been growing since the development, in 1995, of the “Innovation on Production” survey (Kinkel et al., 2007) by the Fraunhofer Institute for Systems and Innovation Research. This survey gathers together responses from a total of 13,426 German firms having undertaken any relocation of the production activities. The survey is updated once every two years, starting from 1995. Respondent companies are grouped by dimension and by sector. The updating process allows researchers to understand the trends and the related variation on the relocation of production activities. Data on German firms suggests that countries entered in the EU during the 2004’s expansion, together with several Asian countries[3], are very attractive markets for a relocation of production. As regards eastern European countries, the most attractive destinations for the relocation of the German firms’ activities, turned out to be Hungary, Poland and Czech Republic (Kinkel et al., 2007).

Alongside with the Innovation on Production survey, the Fraunhofer Institute developed another survey in order to analyse the techno-organizational innovations in European firms, and consequently, also the differences in productivity for those firms. The European Manufacturing Survey (EMS) is a collection of innovations and strategies, whether they concern the production or the offshoring, in 2249 companies from Austria, Croatia, France,

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[3] The most frequent destinations for offshoring in Asia are China, Philippines in a larger share, followed by Indonesia, Malaysia and Vietnam (Lewin and Peeters 2006). Furthermore, some evidence of relocation activities has been tracked also towards South Korea, Taiwan and Singapore (Lewin, Massini, and Peeters 2009).

Germany, Great Britain, Italy, Slovenia, Switzerland and Turkey (Dachs et al. 2006). The complexity and richness of the data allows also to obtain information on a larger extent regarding the relocation of activities for the firms under analysis. As an example, the data of the EMS showed that, on average during the years 2002-2003, Austrian firms present in the sample are the ones that have offshored more (57%) of their production activities towards the eastern European countries, while for the German firms, this figure amounts to 46%. The trends regarding the offshoring decision is also enhanced by the EU enlargement in 2004, towards the Czech Republic and Poland.

On the one hand, according to a more geographical extensive analysis of EMS's data, it is possible to highlight that, on average, those eastern European countries which have entered the Union in 2004 have had the important role of accelerating the process of the relocation of activities. On the other hand, western European countries have been attractive destinations for companies based in Austria (41% of the sample), Switzerland (30%), Germany (27%) and United Kingdom (25%) (Dachs et al. 2006). However, these scenarios have occurred following different underlying perspectives (Kinkel, 2012), described in Section 1.1.3.

An interesting picture is given by the firms that undertook an RHC for their production activities: UK, together with France and Austria, shows a percentage of companies coming back which is higher than 15% of sample's firms. On average, for every western European country, the fraction of firms returning to the home country fluctuates from one sixth to one half, as in the case of Italy (Dachs et al. 2006). This consideration is confirmed by Kinkel et al. (2007) according to whom, the ratio of firms relocating their production back to their home country is measurable and significant in the survey's sample. On the opposite side of the analysis, during the time span 2009-2012, the countries from which the companies undertaking a RHC are repatriating their activities are mainly China, India (30% of all the RHC cases) and the EU12 (21%) (Dachs and Cristoph 2014).

Pushing forward the analysis to what concerns the features of the offshoring firms, the work by Kinkel and Maloca (2009) evidence a higher propensity to undertake a RSD decision in those companies that implement more labour intensive processes. As opposed to this trend, companies working on more capital-intensive processes seems to show a lower propensity to proceed in a RSD of their production activities. In addition to this, it is possible to observe that, among those companies that had already offshored a part of their production capacity, there is a direct correlation between the level of the technology implemented and the propensity to opt for RHC. In particular, the high technology and medium-high technology sectors account for, respectively, 7.5% and 5.3% of the total firms in the EMS. Going into a deeper understanding of those companies, the ones belonging to the pharmaceutical, the computer and the electrical equipment sectors are the most footloose in terms of both offshoring and then RHC (Dachs and Cristoph 2014).

Changing the perspective, it is useful to look at when the decision to relocate the production activities at home is made. Thanks to the data of the Innovation on Production survey, it is possible to observe the temporal interval occurring between a company's offshoring decision and the RSD decision. Specifically, on average, for the 17% of firms the second relocation event occurred 4.5 years after they had undertaken the first relocation decision, having experienced the offshoring between 2001 and 2011. Furthermore, the 10% of firms that have offshored their manufacturing operations between 2004 and 2006 experienced the RSD 2.5 years after the first one (Fratocchi, Equizi, et al. 2013). Still related to the temporal dynamics characterising the reshoring phenomenon, the EMS data offers a clue about the influence of the economic crisis that started in 2008. During the period in which the crisis struck Europe, data showed a decline of the phenomenon of offshoring (Kinkel 2012). On the other hand, the trend of RHC decisions maintained a similar pattern compared to the pre-crisis period, since the percentages did not diverge from previous observations. In fact, the share of firms in the EMS's sample that have performed a RHC concerning their production facilities has been 2.4% in the 2004-2006 period, and 2.8% in the 2007-2009 period (Kinkel 2012). This figure, remained very small, suggests that, at that stage, the relocation back to the home country could not be considered as a mean for the growth of manufacturing economy and employment in western Europe countries (Dachs and Cristoph 2014).

Alongside with the EMS, other databases were developed as an instrument to research in the field of RHC strategies. One of these examples is the Danish questionnaire-survey that gathered all the possible relocation strategies, independently of the type of the operation conduced. The survey has been developed by the Department of Entrepreneurship and Relationship Management, University of Southern Denmark (Arlbjørn et al. 2016). The database encompasses 843 Danish manufacturing firms, the 2.1% of which have moved production back to Denmark (Arlbjørn and Mikkelsen 2014). This result is in line with the data emerging from the German Manufacturing Survey and the EMS.

One of the most recent – and, potentially, most significant for the research purpose – datasets is that one developed by the Uni-CLUB MoRe Back-reshoring Research Group. This database consists in a collection of data from secondary sources and contains data regarding the transfer of production capacity involved in each relocation decision of sample's companies. In particular, the data includes information about the country of origin, industry, year of the implementation of the RHC and host country (Fratocchi, Barbieri, et al. 2013). This database has provided some important hints on the relocation phenomenon: for instance, 70% of the RHC operations regarded China and other Asian countries, while Eastern Europe countries consist in 10% of the total sample. Furthermore, comparing the analysis carried out on this data and the one presented before, it can be highlighted an increase in the relocation occurrence in the period following the economic crisis; again, in contrast with Kinkel and Maloca (2009), no significant difference can be observed comparing events related to labour and capital intensive firms. Data also show that Italian; German and French firms implemented "multiple reshoring strategies"[4]. In addition to this, the information contained in the Uni-CLUB MoRe data set suggests that *near-reshoring* activities are the most common RTC practice among European countries and that RHC initiatives are equally distributed among Northern America and Europe (Fratocchi et al. 2015). Changing the perspective and looking at the industrial patterns of reshoring, Fratocchi et al. (2015) highlight how companies in the clothing and footwear industries are the most active both in terms of RHC and RTC (*near-reshoring* in particular), followed by electronic and mechanical firms. It is also important to notice that, in many cases, the activities that are reshored are the ones with the lowest value added, while the ones adding the highest value to the firm's business are usually kept into the home country. As the Uni-CLUB MoRe data shows, the Information and Computer Technologies (ICTs), call centres and software development are the business units that are more likely to be reshored, with percentages of 24.78%, 18.58% and 13.27% respectively. Conversely, the high-value adding activities – namely, product design, engineering and R&D – can be enhanced in terms of productivity by reshoring operations (Albertoni et al. 2015).

[4] With the term "multiple reshoring strategies" it is meant the strategic behaviour by some companies to relocate more than once (from 2 up to 8 times) their activities. Among these is worth a mention for 47 companies of the Uni-CLUB MoRe data set (Albertoni et al. 2015; Di Mauro et al. 2018).

Finally, one of the most important databases for the purpose of this dissertation is the European Restructuring Monitor (ERM). This database has the aim of monitoring the employment effects of relocation events by collecting data and publishing fact sheets on large-scale restructuring announcements by European and foreign firms operating, directly or through subsidiaries, in the EU28 countries plus Norway. Data have been collected starting from 2002, so far encompassing more than 22,000 recorded restructuring events. Differently from the previous databases, the information of the ERM is publicly accessible. From this data set it is possible to infer that relocation initiative have peaked right after the European enlargement of 2004 (Barbieri et al. 2018). It is interesting to notice that the RTC have a geographical trend towards concentration in eastern Europe countries like Poland, Hungary and Czech Republic; on the other hand, RHC events have France and Italy as main targets.

All these movements show that RTCs are originated from the medium/high wages countries and are directed to lower wages countries (Barbieri et al. 2018). The role of the wages as well as all of the possible motivations for the RSD will be thoroughly discussed in the following section.

1.1.3 Motivations for reshoring activities

After having depicted the conceptualization and the main trends regarding reshoring, I now move to a discussion on the motivations and the drivers of the RSDs.

One of the principal issues regarding RSD decisions is the concept of the *managerial error* (Di Mauro et al. 2018). The term "managerial error" is intended as a wrong evaluation of the potentially achievable advantages that a new geographical location for the production facility of a firm would provide. According to Kinkel and Maloca (2009), it is possible to observe that, in many cases, the RHC decision is often influenced by a mistake in the evaluation of the costs and the benefit after the first offshoring one. In some cases, both the first and the second decisions are defined as "flawed", basically referring to the behavior of the managers involved in the offshoring decision (Gray et al. 2013). Among the behaviors adopted by managers in the decisions, it is possible to highlight what Abrahamson and Rosenkopf (1993) have advocated as "bandwagon effect". The term refers to the imitation of the conduct of other managers (Mariotti, Mutinelli, and Piscitello 2008) that could have represented a driver for the enhancement of the number of offshoring decisions. In particular, the term has a negative connotation, being used to describe a behavioral aspect of those decisions that have revealed themselves to be failures or disappointing in the following years. Another factor causing a flawed reshoring is an overestimation or underestimation of the "hidden costs" that the company has to bare after the reshoring (Gray et al. 2013). Basically, the RHC decision can be considered as a reaction to some unmet expectations that the company had at the time of the first relocation (Albertoni et al. 2015).

Referring to the extant literature, it is possible to go into a deeper level of analysis about the authentic factors that could have led to an offshoring and then to an RHC decision. With this respect, the first element that academics consider as a fundamental determinant is the *cost differential*. Specifically, according to Dachs et al. (2006), it is possible to observe that an overall reduction of production cost is the main reason for an initial relocation, followed by an opening of *new markets*. Against this view, Kinkel et al. (2007) prove wrong that the two factors, namely the production costs and the possibility to create new markets, as far as concerns the first offshoring decision, have the same influence.

Data confirms this difference in the order of magnitude of the factors' impact: costs, in fact, have a bigger importance for the firm responding to the German Manufacturing Survey, than any other variable. Conversely, the general choice of a RSD is influenced by *quality* issues and the difficulty to find *qualified personnel* in order to deliver a product with the requested features. Such an evidence is enforced by Fratocchi et al. (2016), which states that there is a strong disconnection among the reasons for the first offshoring to the ones for the second degree decision.

In addition to the motivations presented above, the Innovation on Production survey provides further evidence. In particular, those companies that have offshored part of their production pursuing a cost reduction through the labor component encountered some issues in terms of the low qualified personnel. From the survey emerges that the critical factors in RHC decisions are quality of the production, *proximity* to the customers, *coordination costs*, quality of infrastructure and qualified personnel. (Kinkel and Maloca 2009). The matter of the labor cost is broadly discussed, keeping into consideration the implications and the external factor, such as the economic crisis of 2008. First, it is important to note that, the crisis caused an overall decrease of the foreign direct investments (FDI) flows, but, this statement is consistent for the first relocation events, the RSDs kept constant in percentage during the period, as already shown (Kinkel 2012). For what concerns the cost-oriented relocations, Kinkel et al. (2007) find a correlation between the number of firms that offshored their production and a decrease in the level of employment in their home country, highlighting a potential pursuit for less labour-expensive locations. It is important also to point out that, as shown by Kinkel (2012), during the crisis period, no evidence is showed backing the idea of an increasing importance of the labour cost in the decision for a relocation. Moreover, the same author explains RHC operations as an attempt to concentrate "production capacities, trying to exploit the benefits of higher capacity utilisation and a superior relation of variable costs to fix at their existing locations" (Kinkel, 2012, p. 155). This usually happens during a period of recession, when a decrease of the overall consumer demand would cause an excess of the total production at all the stages of the supply chain. In fact, if a company controls many facilities in different locations, in case of a contraction in consumers' demand, the theoretical reaction would be to concentrate all the production capacity into the home country plants. Many authors tried to summarize and organize the determinants for RHC. Five significant categories for back-reshoring determinants can be defined: labour costs; logistic costs; host country characteristics; home country-related features; firm specific factors.

For what concerns the labour costs, the progressive shrinking of the labour costs differentials had played the most important role in the decision making for a large number of firms in both the EMS (Kinkel 2014) and the Uni-CLUB MoRE datasets (Fratocchi et al. 2014). As shown in Figure 1.1, in the timespan 2000-2015, the factory-worker wages in China grew from the 3% to the 17% of the average wage for an American worker.

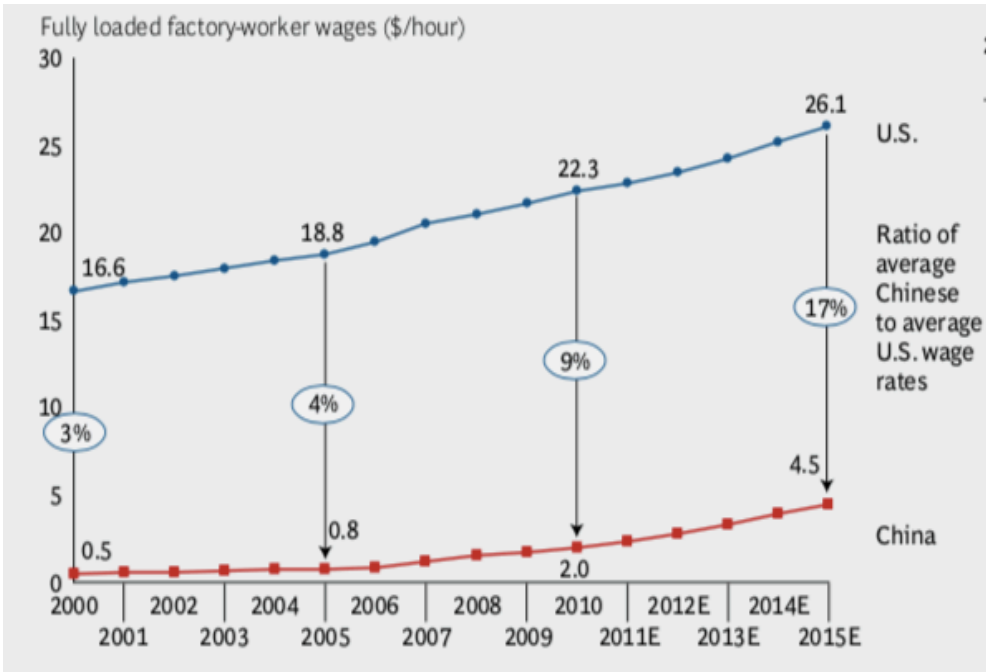

Figure 1.1 - Comparison of the factory-worker wages, China-USA. Source: BCG (2013)

Regarding the logistic costs, a higher than expected increase of them could be one of the factors. Against this view, Kinkel (2014) and Dachs and Cristoph (2014) show that, for most of the interviewed firms, the increase of the logistic costs has an influence significantly smaller than other reasons. For instance, as described above, one of such other reasons is the effective quality of the products manufactured abroad. The logistic aspect is analysed also by the World Bank in the computation of the Logistic Performance Index (LPI)[5]. The LPI is a helpful indicator to understand which challenges and opportunities for countries in trade logistics are. Figure 1.2 shows the differences in the scores of the LPI for some countries

[5] The LPI is described as a statistical instrument of the logistic performance of a single country, it takes into account the international and domestic perspective. It is based on some sub-indexes measuring the performances in terms of: customs, infrastructure, international shipments, logistics quality and competence, tracking and tracing, timeliness. [Source: https://lpi.worldbank.org/]

included in the EMS survey, both as target and origin of reshoring operations, and the United States, included as a reference.

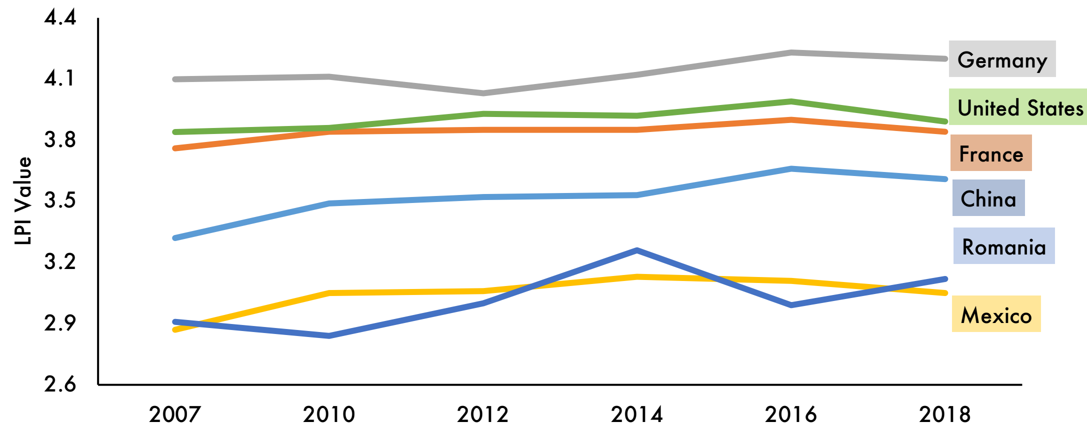

Figure 1.2 - Trend in LPI for six countries. Source: World Bank. Own Elaboration.

Shifting the attention to the quality aspect, the poor quality of the production is one of the topics belonging to the category of the host country characteristics. In the dataset derived from the German Manufacturing Survey, this topic is resulted to be the second most influent reason for the RHC of production activity (Kinkel et al. 2007; Kinkel and Maloca 2009). In the framework by Fratocchi et al. (2015), also the availability, the skills and the productivity of the workforce belong to the pool of the host country characteristics. Another motive for back-reshoring related to the host country is the perceived possibility to lose part of the know-how (Dachs and Cristoph 2014). Among the home-related factors, it is possible to point out, as the most significant, the "made-in" effect (Albertoni et al. 2015). The rationale supporting the importance of this factor is that a distinctive and value-adding feature of a product resides in the fact that is manufactured only in a certain country granting quality- and competition-distinctive characteristics. This idea implies an obvious value for the high-income country such as Italy, US, France and Germany. A significant influence of the "made-in" effect is exemplified by the answers of some managers of firms in the Uni-CLUB MoRE survey[6] (Di Mauro et al. 2018). Another motivation related to the home country consists in the attempts

[6] In the report by Di Mauro et al. (2018), the manager of the all four companies interviewed for the case study mentioned the importance of the "made-in" for their product and so for their relocation decision. In particular, the manager of Ska-Italia emphasized the aspect of the "made-in" label by saying "The high end fashion market demands a made in Italy product, even if sometimes made in Italy is just a cliché rather than a reality" (Di Mauro et al. 2018, p. 119)

of some government (the US are the main example) to encourage firms that had previously offshored their production abroad to repatriate their production activities (Ellram et al. 2013). This particular topic is considered by Fratocchi et al. (2015), but, on the contrary in the EMS there is no evidence that managers consider those incentives and concessions as a real enabler for the repatriation of their activities (Dachs and Cristoph 2014).

Changing the perspective, the firm specific factors that academics address as reasons for the RHCs are two. The first one, refers to the value chain concept and consists, basically, in the pursuit of a reduction of the physical distance between the value-adding activities of design and production[7] (Doh, Bunyaratavej, and Hahn 2009). The second one, on the other hand, is referred to the firm that have undertaken investments in automation; those investments are made by firms in the country where there are more possibilities to obtain a more advanced and more reliable technologies. Therefore, those firms adopt a back-reshoring strategy to their home country (Arlbjørn and Mikkelsen 2014). This last point of discussion is of great importance for my later discussion and will be further developed in subsequent sections.

A different framework for the gathering of the variables influencing a RHC decision is presented by the work of Fratocchi et al. (2016). All the variables gathered by the survey and the interviews of the Uni-CLUB MoRe data set are grouped and divided into two dimensions. The first dimension encompasses a distinction regarding the origin of the influencing factor, the division is among "internal and external environment variables". The internal aspect is referred to the *firm-specific factors*, while the external aspect refers to the *country-specific factors*. The second dimension refers to the "customer perceived value" and to the "cost efficiency". The "customer perceived value" could be defined as "the customer's perceived preference for an evaluation of those product attribute, attribute performances, and consequences arising from the use that facilitate (or block) achieving the customer's goals and purposes in use situation" (Woodruff, 1997, p. 142). Conversely, "Cost efficiency" considers the minimization of the overall costs by increasing the productivity or reducing the various production expenses (Fratocchi et al. 2016). In the framework (Figure 1.3), all the variables are ordered according to the dimensions and the relative importance is attributed by the number of managers of firms in the Uni-CLUB MoRe that responded by defining these

[7] As a matter of fact, distance is seen as an obstacle to the full realisation of the expected value deriving from the cited activities (Doh et al. 2009).

motives as relevant for their decisions. Some of these variables, can be considered as occupying two quadrants, as it can be seen in Figure 1.3. The figure also reports in brackets the relative importance of each factor, according to the data on the survey of Fratocchi et al. (2016). The most frequent motivations are the logistic costs, for what concerns the cost efficiency, and the delivery time, in the field of the customer perceived value, both of them are related to both the internal and the external environment. The labour costs' gap reduction is the third-most mentioned factor for the production relocation, in the cost efficiency/external environment quadrant. Other important factors are the made in effect and the poor quality of products in the customer-related/external quadrant (Fratocchi et al. 2016).

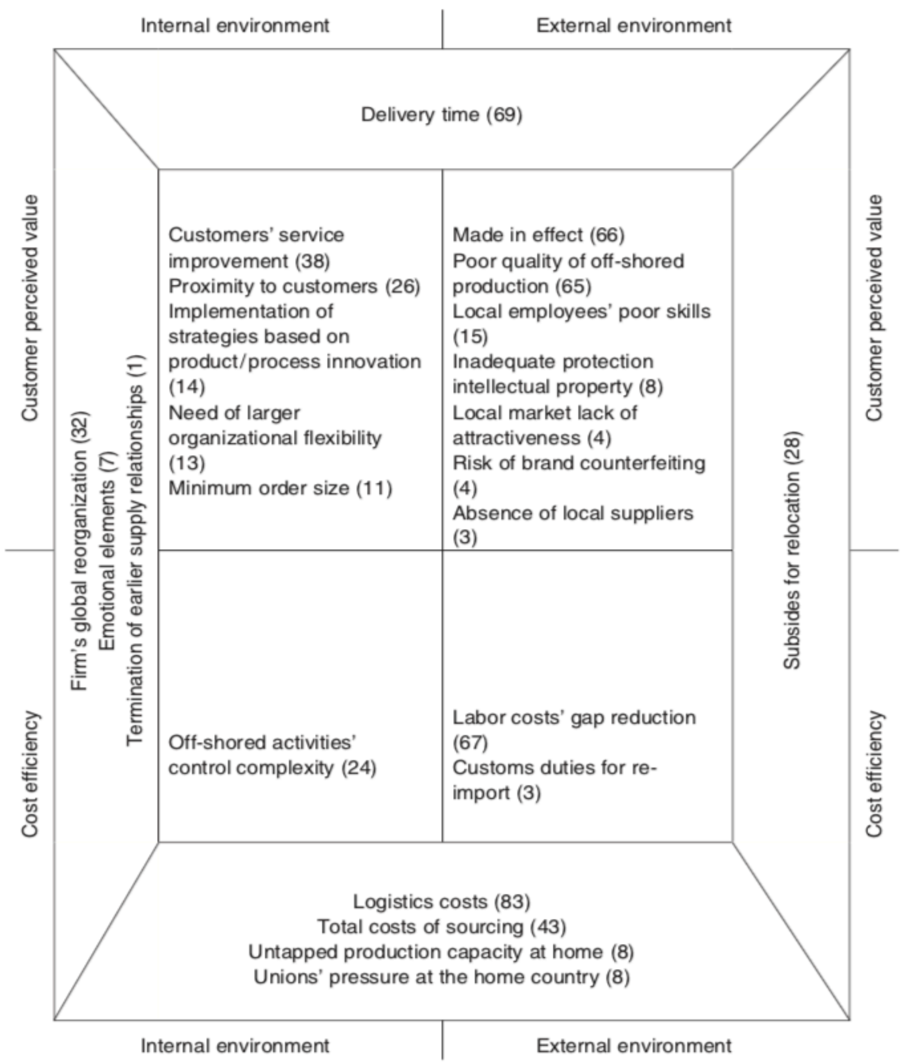

Figure 1.3 - Framework of the motivations for reshoring. Source: Fratocchi et al. (2016)

In addition to the five sets of variables and the four-quadrant framework proposed by Fratocchi et al. (2016), another framework is proposed by Barbieri et al. (2018). This framework relies on the internationalization drivers proposed by Dunning (1993), namely *market-seeking*, *strategic asset-seeking* and *efficiency-seeking*, the latter sub-divided into two indexes: *cost reduction* and *productivity enhancing*. Following this distinction, the Uni-CLUB MoRe tried to summarize which of these drivers has an effect on the relocation probability, with a distinction between RTC and RHC (Barbieri et al. 2018). In the investigation, the drivers are built on statistic data, not just variables gathered by interviews or surveys as happens in the EMS and Uni-CLUB MoRe dataset. For market-seeking, the researchers used the difference between the first host country and the home country in the Gross Domestic Product (constant 2011 USD at Purchasing Power Parity, data from the World Bank). The strategic asset-seeking driver is represented by the difference between the first host country and the home country of the researchers in R&D per million people (data from the World Bank). The efficiency seeking driver is built with a cost-saving sub-driver, defined as the difference between home country and first host country of the Unitary Labour Cost, being the base year 2010=100 (data from the OECD); while the productivity-enhancing sub-driver is the difference between the first host country and the home country in the ratio GDP per person employed in constant 2011 USD at Purchasing Power Parity (source: World Bank, International Labour Organization, ILOSTAT database). A statistical analysis has been conducted on the numerical data and the numbers of firm relocating towards a third country or the home country. The data from the Uni-CLUB MoRe, suggested that the relocation to the third country, RTC, could be a preferred choice if the first-degree decision is driven by efficiency-driven reasons. In this perspective, it is possible to affirm that the company that have tried to pursue cost reduction and productivity increase will try to pursue this goal in a third country. On other hand, Barbieri et al. (2018) suggest that the RHC, will be a preferred choice if the first-degree relocation has been conducted by a firm that is pursuing a market-seeking location advantage.

The conceptual map shown below aims in categorizing and summarizing the major schemes for the determinants of the RSD. The first category comes from the anecdotal and unstructured literature that refers to the "quality issues" and the idea of the "concentration of the productive capacity". Underneath is depicted the 5-determinants frame of mind suggested by Fratocchi et al. (2015). The advancement in this view is given by the organic disposition of the determinants and an overview that covers aspects both inside and outside the manufacturing plant, in particular with the presence of home country characteristics and the host country characteristics (Fratocchi et al. 2016). The third typology of determinants is represented by the two-axis graph that categorizes the variables on the internal and external dimension, with respect to the company and the distinction to the cost-related factors and the customer-related ones. This framework gives a complex representation of the space of the determinants, and the possibility, for a further investigation, to distinguish the single variables according to the typology of the firm.

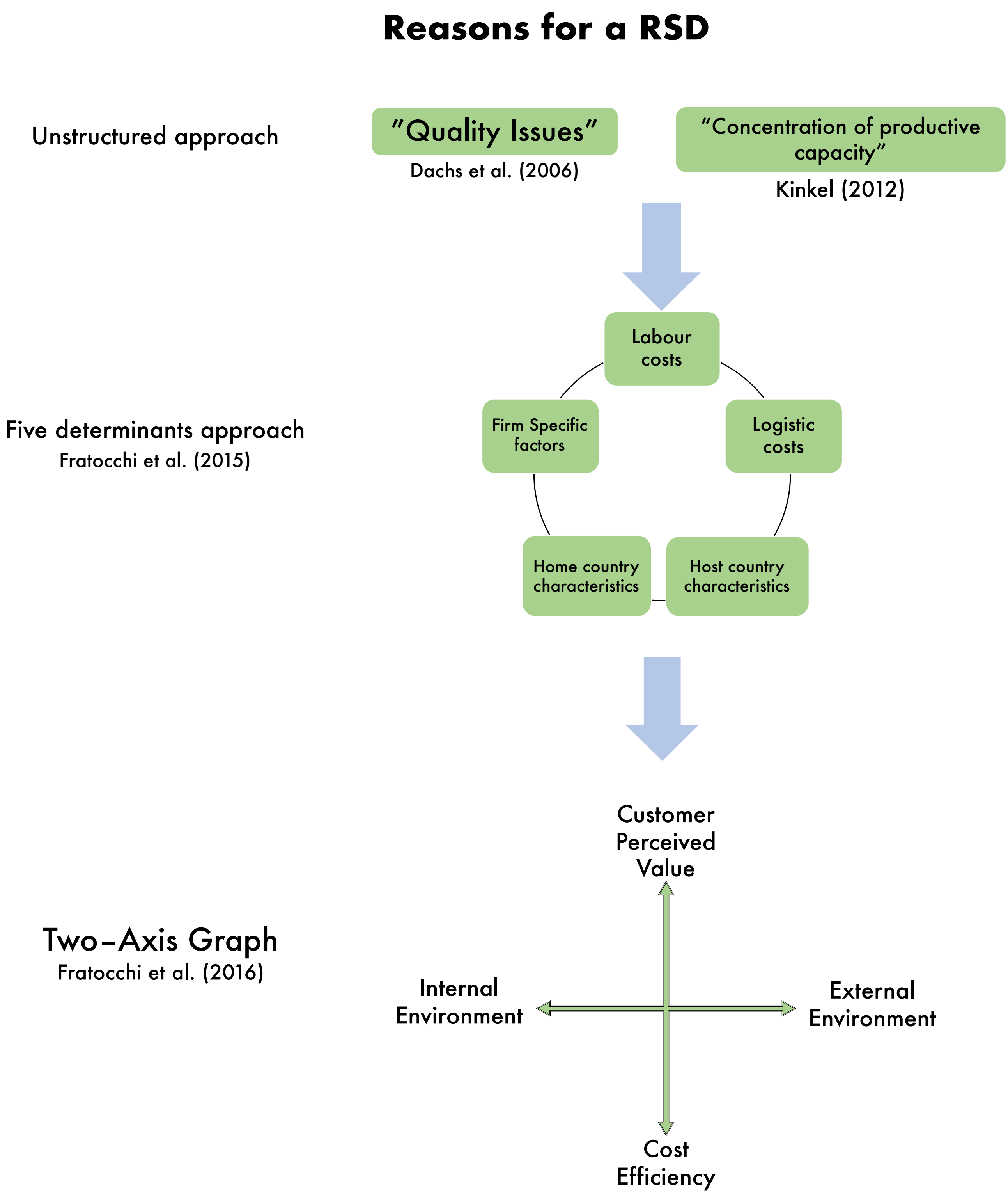

Figure 1.4 - Comprehensive framework for the driver of the RSD. Own Elaboration

1.2 Technological developments in the advanced countries

1.2.1 Overview of the initiatives

In the last few years, the advanced countries have progressively witnessed an extraordinary improvement of the technologies for industrial production. Many scholars in engineering and economics refer to these new technological developments as the "Fourth Industrial Revolution" (FIR) (for instance, Lasi et al. 2014; Albers et al. 2016; Lu 2017). The term FIR has been first introduced by the World Economic Forum, according to which, it consists of a new, unprecedentedly fast incidence of technological breakthroughs that are going to transform entire systems of production, management and governance (World Economic Forum, 2016). In general, an industrial revolution consists in a series of radical innovations that will reshape the cost-benefit trade-off, moving the curve on a higher point on both axis (i.e., shifting up the frontier of technological development).

In order to better contextualize the "revolution" term, the recap of the other three industrial revolutions is given. The first industrial revolution is the name given to the initial mechanization of the production, and the machine of James Watt; during that period the world witnessed an unprecedented growth of the GDP per capita and economic growth in the capitalist economies (Lucas 2003). One of the most important traits of the first industrial revolution is the steam-powered machine, that has been deeply used in the manufacturing and the transportation sector, using the steam locomotives first in the coal mines and then for real mass transportation systems, linking cities with each other. The leading sector of the industrial revolution has been the textile one, in which the implementation of the mechanized looms and aftermath the use of the steam power improved the productivity and the production, creating the industrial society (Landes, 1969). Furthermore, the substitution of coke instead of charcoal, gave the possibility to implement on large scale the hot blast, giving a big push to the iron making industry (Landes, 1969). The industrial and productive improvements of the first industrial revolution are considered the most important event in humanity since the domestication of plants and animals (McCloskey, 2004).

Then, the second industrial revolution is mainly referred to the technological improvements and off the mass production, recorded from the end of the 19^{th} and the beginning of the 20^{th} century (Landes, 1969). The introduction of the Bessemer process and then the Siemens-

Martin process allowed the mass production of steel, that has been used for several applications, like larger bridges, skyscrapers and ships (Birch, 2006). The introduction of steel-made rails, gave the possibility to build railroads at competitive costs and whose rails lasted more than ten times the iron-made rails of the pioneer's era of train transportation (Fogel, 1970). Another aspect of the second industrial revolution is the mass usage of the electric power and the development of the machine tools. Another important breakthrough related to the second industrial revolution is the development of the automobile, firstly invented and patented by Karl Benz in 1888 and then mass produced, thanks to the implementation of the assembly line by Henry Ford in 1913 (Georgano, 1968). Always in the field of the second industrial revolution, the innovations in the field of telecommunications must be mentioned, like the invention of the telegraph in London in 1837, the patenting of the telephone by Alexander Graham Bell (invented by Meucci), both of them used initially to speed business transactions (John, 2010). Other innovations of the second industrial revolutions are the radio transmission system, invented by Guglielmo Marconi, the use of ammonia in agriculture as fertilizer, the vulcanization of rubber by Charles Goodyear and Thomas Hancock, the invention of the modern bicycle by John Kemp Starley. Furthermore, during the second industrial revolution, there have been some innovations in the field of corporate governance, first with the initial concepts of business management for the railroads services (Chandler, 1977), and then with the development the scientific management theories by Frederick Winslow Taylor, also known as Taylorism (Mitcham, 2005).

Finally, the third industrial revolution is the widespread usage of ICTs, hence, this is called the Digital Revolution (Schoenherr 2004). This era of technological development began in the '40s of the 20^{th} century, with the invention of the transistor, giving the possibility to implement digital computers in manufacturing plants.

Right now, the spreading of the FIR is not only considered an ulterior step forward with respect to the previous advancements, but rather a rethinking of the production system, in order to develop an intelligent connected and decentralized approach to production (Albers et al. 2016). The FIR is based on concepts coming from two distinct perspectives: high level industrial concepts and on technical issues covering the usage of specific technologies (Armbruster et al. 2005). In particular, the high-level issues are related to the field of production management, the general aims in this perspective are: *short product development times*, *enhanced efficiency in the usage of production factors* and a *geographical decentralization of manufacturing* *and consumption locations*. The latter, instead, represent the instruments at the basis of the newest technologies advancements are: Cyber-Physical Systems (CPS); Internet of Things (IoT); Smart Factories; Big Data; Cloud Computing (Lasi et al. 2014b).

If looking at the geographical spread of these concepts and technologies, the countries which shows the highest competitive advantage in their implementation – and, coherently, in the development of the related innovations – are the European countries. In facts, as can be evinced by the EMS, Switzerland, Austria and Germany record the highest percentages of companies that implement Enterprise Resource Planning (ERP) software and teleservice instruments. Furthermore, already in 2004, data of the EMS shows that, on average, half of the surveyed companies had implemented ERP software for production, planning and control and delivery (Armbruster et al. 2005)[8]. Looking at a different side of the new industrial development, the remarkable points that this late revolution is trying to score is the improvement of industrial production through flexibility, cost reduction, improved productivity, improved quality and delivery time reduction (Moeuf et al. 2018).

The diffusion path of the aforementioned technological improvements can be described by two directions: "technological push" hence, driven by individual investments and "application pull" with economic, social, political changes as triggers (Armbruster et al. 2005). The concept of "application pull" is exactly the main trigger for the widest adoption of advanced technologies related to the FIR. In fact, the initiative "Industrie 4.0", launched in 2011 by the *Bundesministerium für Wirtschaft und Energie* (German Federal Ministry for Economic Affairs and Energy) has been, for the whole European continent, the beginning of a renewed period of strong focus – by both policymakers and firms across all Europe – towards the adoption of industrial innovations. With the initial launch of the initiative, Germany has been the precursor for all the government-driven initiatives in most of the European countries, especially the western ones. Other noteworthy initiatives launched in the European countries are the "Factory of the Future" in France, "Piano Nazionale Industria 4.0" Italy, and

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[8] In addition to the technical improvements, as the ones related to the production management and the technology, the researchers find that the European firms proceeded in the adoption of some non-technical innovations (i.e. teamwork, continuous improvement), that could be placed side-by-side to the technical ones. EMS data show that the firm that rely most on the non-technical concept, like continuous improvement are the Slovenian (86% of the surveyed firms), followed by Austrian, Turkish and French (79%). Source: EMS 2003/2004

“Catapult” centres in the UK. Other initiatives are developed at European level, directly by the European commission, in order to foster growth of the high-technology improvements in some country, and, in other cases in particular regions (EU 2018b). Outside of the European Union, the United States are promoting a campaign based on the advanced manufacturing, thanks to the institution of the National Network for Manufacturing Innovation (NNMI), also known as Manufacturing USA (NNMI 2011). The network is composed by 15 institutes that operate independently in order to promote the development of new manufacturing technologies in different areas of competence (Deloitte 2017).

As some of the names of the national initiatives suggest, the governments are trying to promote the development and the large-scale implementation of the new technologies, by adhering to the concept of the FIR. Thus, the general definition of the stream of new practices and technologies take the name of Industry 4.0 (Lasi et al. 2014b; Deloitte 2017, 2018; EPO 2017).

The Industry 4.0 approach has a characterization that is represented in literature by various frameworks. One of the most important is the one formulated by Stock and Seliger (2016). This particular structure is based on two typologies of perspectives, distinguished in two levels: macro and micro. Furthermore, the framework proposed examines three concepts: horizontal integration, vertical integration and end-to-end engineering. The horizontal integration, in this framework, is covered by both the macro and micro perspectives, while the end-to-end engineering is peculiar of the macro perspective and the vertical integration is framed in the micro perspective (Stock and Seliger 2016).

The horizontal integration is defined by “an interplay of different value creation factors”: the value creation models are interconnected all along the value chain and all the product life cycle of the product (Seliger 2007). The horizontal integration is an enhancer for the Collaborative Manufacturing and the Collaborative Development Environments. These collaborative networks can be useful to expand the range of market opportunities, and to hedge the risk of volatile markets, characterized by shorter product lifecycles and requesting high flexibility (Brettel et al. 2014). The end-to-end engineering, on the other hand, is a wording, that refers to all the phases of the production process, starting from the raw material acquisition until the management of the end-of-life phase of the product (Stock and Seliger 2016). In this case, the phases of production process are monitored and managed with a comprehensive, integrated and digitized approach (Brettel et al. 2014). Figure 1.5 displays the macro level dimensions of the Industry 4.0, highlighting the effectiveness of the horizontal integrations mixed with the end-to-end engineering. The end-to-end engineering is displayed as the collection of all the product life cycles, connected with each other, both with physical flows of materials and the information flows, based on the central role of cloud computing technology. In the macro perspective, the concept of "smart"[9] item emerges, clearly. In fact, all the actors in the production systems must satisfy the smart requisite, in the case of the consumer, the logistics, the factory and also to the energy distribution facility. The latter typology of system, taking the name of Smart Grid, is an interconnected facility that is able not only uses energy but also produces and distributes it to the manufacturing sites. Being smart, all the actors in the value creation process share data in each stage of their activity, resulting in the meaningful advantage of the Industry 4.0 system: the creation of a Smart Data stream, that, in turn, will transform the system into a more interconnected and auto-regulating one.

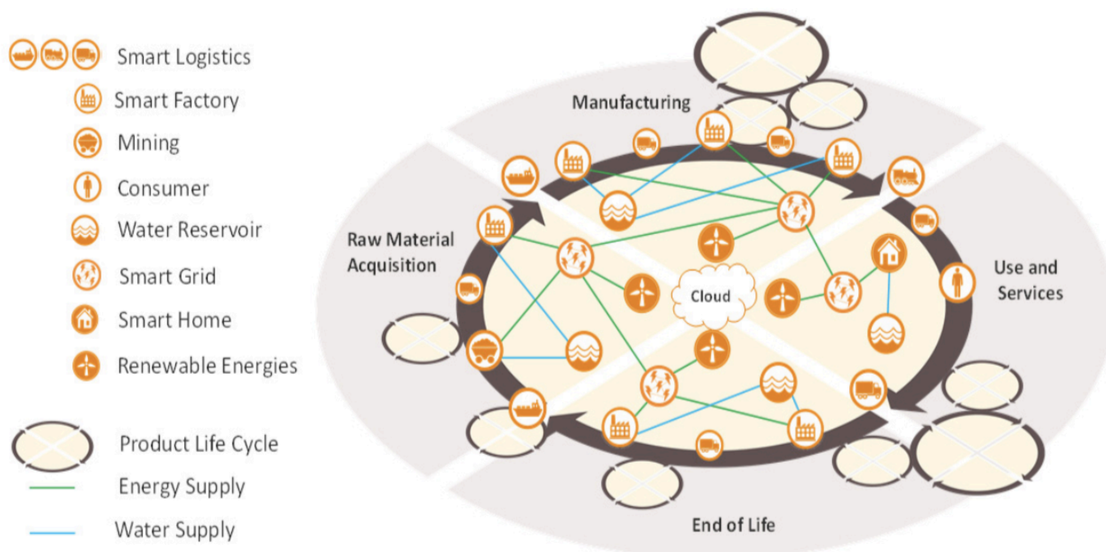

Figure 1.5 - Macro perspective of the Industry 4.0 system. Source: Stock and Seliger (2016)

The second issue regards the vertical integration in the production system. The vertical integration consists in "intelligent cross-linking of the value creation factors: product,

[9] In general, a "smart" object is an item that must satisfy particular conditions in terms of connectivity with the external world and the possibility to store and share information. A thorough description is given in the paragraph regarding the Smart Factory and Smart Cities.

equipment and human, along the different aggregation levels of the value creation modules from manufacturing stations manufacturing cells and manufacturing lines" (Stock and Seliger 2016, p. 539). The vertical integration is a distinctive aspect of the micro-perspective of Industry 4.0. In Figure 1.6, a visual representation of this concept is given, together with the horizontal integration and a recall of the end-to end engineering. The logical items of the macro perspective are now described at the micro level. The horizontal integration, in this perspective is built on the cross-linked value creation modules, regarding the material flows. The vertical integration is instead based on the product, equipment and human factors, along all the aggregation levels of the value creation modules, starting from the single station, through the manufacturing cell up to the whole smart factory (Stock and Seliger 2016).

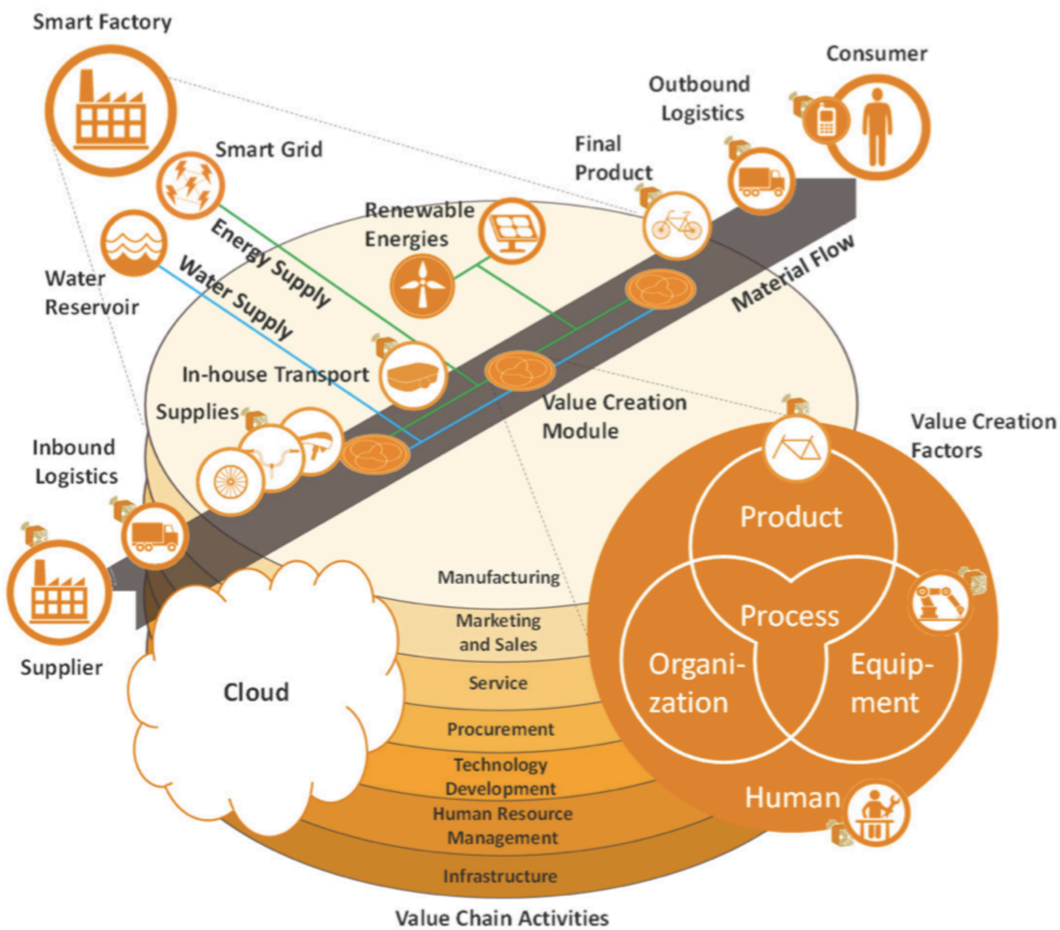

Figure 1.6 - Micro perspective of the Industry 4.0 system. Source: Stock and Seliger (2016)

Alongside with the aforementioned concepts, it is important to mention the idea of the Individualized Production, that is a taking to the extremes of the concept of the Mass Customisation (Fogliatto, da Silveira, and Borenstein 2012). The Individualized Production represents an answer to the growing request by the customer base for products that are more and more different, customized and tailor-made. The increasing importance of the mass customization requests a transformation of the productive systems. In order to have individualised product, it is fundamental to have economies of scale and scopes along the value chain (Brettel et al. 2014). In order to reach the outcome of the Individualized production, the productive system should be reorganized with a decentralized and flexibility-oriented approach and trying to obtain Reconfigurable Manufacturing Systems. Those systems enable manufacturing companies to reorganize their productive scheme, in a cost-efficient way, making possible to satisfy the different needs of all the heterogeneous customer base. In fact, all the mechanic modules can be moved and rearranged according to the mechanic module interface and the demand requirements of the manufacturing firm (Brettel et al. 2014).

1.2.2 Overview of the Components in the Industry 4.0

Cyber-Physical Systems

One of the fundamental components at the basis of the Industry 4.0 is represented by the Cyber-Physical Systems (CPS). Those systems are defined as "the convergence of the physical and digital world by establishing global networks for business that incorporate their machinery, warehousing systems and production facilities" (Shafiq et al. 2015, p.1149). The adoption of the CPS is consistent with the integration of the activities along the value chain and in all the stages of the lifecycle of a product (Stock and Seliger 2016).

Going into a further level of analysis, the CPS are generally based on a scheme made of five logical tiers (Lee, Bagheri, and Kao 2015). These five levels, also called the "5C", are:

- (smart) Connection: each working machine is equipped with sensors that measure in real time the performances and the working conditions of the machine.
- Conversion: information has to be inferred from the data, with specific and extensive algorithms, in order to obtain reliable data about health value, remaining useful life etc.; this is the level in which the machine obtain its self-awareness.
- Cyber level: the information is used to form a virtual machine network, specific information is extracted to provide better insights over the status of each machine in the fleet; moreover, some predictions about the future status of the machine can be made.
- Cognition: generation of a deep knowledge of the monitored system; for this level, in order to show the knowledge to the users and to support their decisions, some info-graphics are necessary.
- Configuration: this is the final feedback from cyber space to physical space. In order to apply corrective and preventive decisions, the modifications are implemented to the physical machines.

Changing the perspective of the definition it is possible to affirm that " CPS are systems of collaborating computational entities which are in intensive connection with the surrounding physical world and its on-going processes, providing and using, at the same time, dataaccessing and data processing services available on the Internet" (Monostori et al. 2016, p. 621). According to Lu (2017), CPS make use of micro-controllers, sensors and actuators, exchanging information among computer terminals and applications, in order to collaborate in modelling, planning, designing and the maintenance in the manufacturing process.

Beside the logical functioning of the CPS, it is important to highlight that those systems are not an improvement of the "traditional" automated control systems (Wolf 2009), but rather a full rethinking of the shop floor level in a new perspective (Bagheri et al. 2015).

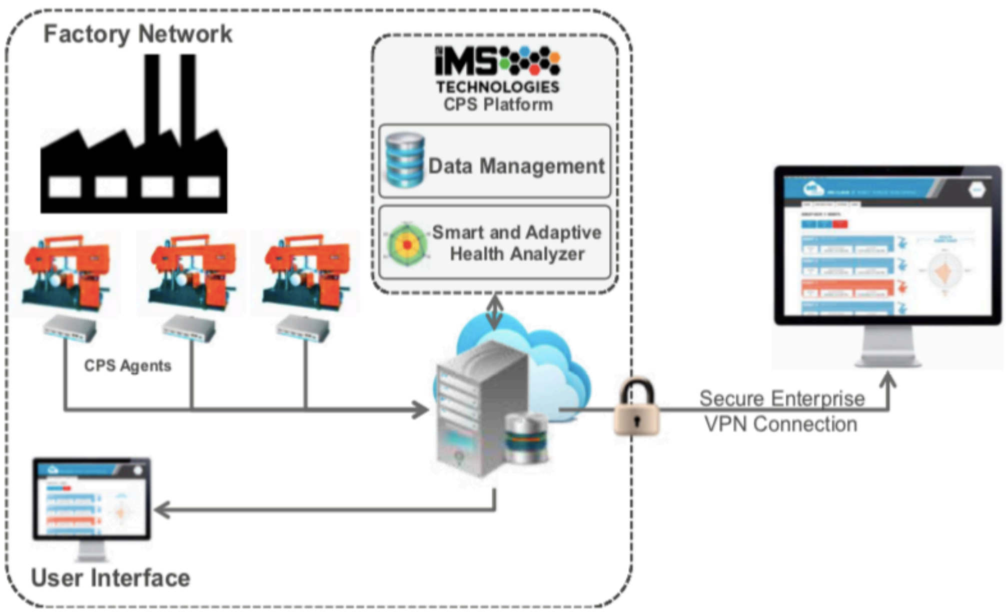

Figure 1.7 - Conceptual representation of the CPS in a manufacturing firm. Source: Bagheri et al. (2015)

Among the logical levels of the cyber physical systems, the Cyber level has a particularly important function, besides the ones already mentioned: it can build virtual clusters of interconnected machines. These virtual groupings are meant to obtain a fully working advanced demand management system (Bagheri et al. 2015), able to forecast, plan and manage the demand of finished product in an autonomous, integrated and reliable way, exploiting all the possibilities given by the high level of connectivity and self-regulation features of the CPS. The CPS are already equipped with the necessary algorithm that assign a working machine to an existing cluster if the functioning pattern is known or either create a new cluster if, from the analysis emerges that the interaction between the machines and the requested product is different from the others previously analysed. The creation of these clusters has a close connection with the concept of the "cyber space", for the demand management in the manufacturing firm (Zug et al. 2015). For "cyber space" it is intended a virtual copy of the factory, in which there is a representation of the machines, in order to conduct also some simulations regarding the functioning of the machines and to extract data in order to obtain insights about the possible optimal configuration of the system. Thus, an important aspect of the Cyber-Physical Systems, in particular of their Configuration level, is the possibility to create an efficient network of virtually interconnected facilities and machines (Brettel et al. 2014).

Of course, a full implementation of the CPS has to satisfy some requirements, in particular (Baheti and Gill 2011):

- Standardised and reliable abstraction in the modelling and design of the systems;
- A development of a complex coupled physical environment, in which the system can reach the desired performances;
- Highly dependable and reconfigurable hardware components, in order to further extend the system in the future.

There are two noteworthy issues in the implementation of the cyber physical systems. The first one is the high cost of the components of the systems, not only the sensors, but all the surrounding information system (Baheti and Gill 2011). The second drawback may come out from the error management of the machines, especially, the ones addressed to conduct manipulating tasks in the Cyber Physical Systems (Zug et al. 2015).

Smart Factory and Smart Cities

In the recent years, the concepts of "smart factories" and "smart cities" are gaining relative importance, especially, in the landscape of the Industry 4.0 development. Moreover, the adjective *smart*, is often coupled to other terms like smart products, or, the smart grids (Lu 2017). In general, to conceptualize a smart object, the author refer to the definition of Radziwon et al. (2014 p. 1185), according to whom, the adjective is "used to characterize an object that was enhanced by implementation of additional features, which introduce multiplatform communication and increase its computational abilities". This conceptualization is an advancement and a complement for the one given by Raji (1994), which refers to a smart object as a device equipped with at least one sensor, and/or an actuator, a microcomputer and a transreceiver.

Following the definition of what a smart object is, the specific concept of smart factory can be identified. First, the concept of *ubiquitous factory*, referring to the possibility for the factory to gather information about the production process, anywhere, anytime, in the most complete way (Yoon, Shin, and Suh 2012). The second concept is referred to the wireless connection of every device in the factory; in fact, each instrument must be assigned an IP (Internet Protocol) address (Zuehlke 2010). Furthermore, the connectivity must also be enabled by the presence of other type of connections, whether, they are Wireless, Bluetooth or others (Lucke, Constantinescu, and Westkämper 2008). The third characteristic is referred to the *glocalization*[10] of the factory, which, in a decentralized way, would be able to supply for serving a specific market (Hadar and Bilberg 2012). The decentralized approach, in fact, consists in the aspect of selling and supply global markets but relying also on local partner and alliance in order to achieve shorter lead times, minimizing the stocks, and increasing responsiveness to the supply chain, thanks to the proximity to both suppliers and customers.

Given these three features, it is possible to present the definition of smart factory given by Radziwon et al. (2014):

"A Smart Factory is a manufacturing solution that provides such flexible and adaptive production processes that will solve problems arising on a production facility with dynamic and rapidly changing boundary conditions in a world of increasing complexity. This special solution could on the one hand be related to automation, understood as a combination of software, hardware and/or mechanics, which should lead to optimization of manufacturing resulting in reduction of unnecessary labour and waste of resource. On the other hand, it could be seen in a perspective of collaboration between different industrial and nonindustrial partners, where the smartness comes from forming a dynamic organization."

The definition of Radziwon et al. (2014) aims at putting together all the concepts and the features that are addressed by the other authors to the smart factory. In this definition, in fact, the concepts of the problem solving are overcome by the glocalization of the factory. Furthermore, there is an emphasis on automation, which, by using software or advanced hardware, aims at reducing the waste of resources. The third important element is the

[10] The term Glocalization, obtained by a portmanteau of the words Globalization and Localization, represents the occurrence of both particularizing and universalizing tendencies in social, political and economic systems. [Source: https://www.britannica.com/topic/glocalization]

collaboration among partners and the construction of the dynamic organization is enabled by Internet and the connections inside and outside the factory.

The application of the smart factory will achieve high levels of self-optimization and automation (Lu 2017). So, the widespread diffusion intelligent factories are considered one of the major goals of the Industry 4.0 policies (Roblek, Meško, and Krapež 2016). It is interesting to notice that, the most advanced countries in the application of the technologies enabling the building of Smart Factories are, behind Germany (predictably in first line for this kind of application), Switzerland and Austria. The involvement of Switzerland and Austria in this typology of techniques is given also by the geographical and cultural closeness, together with the absence of any language barrier, with Germany (Armbruster et al. 2005). Therefore, Germany, could be considered a sort of centre of gravity for the diffusion of the advanced technologies. Recalling the importance of the pioneering launch of the initiative "Industrie 4.0" in 2011 enforces the role of Germany as centre of gravity for the diffusion of the new technologies, as far as European Union is concerned.

To define the smart city, it is important to consider that other disciplines, besides the technical ones must be involved, like economic, human and legal aspects (Lom, Pribyl, and Svitek 2016). A smart city, is made by a combination of some communication networks, like a wireless broadband network, a broadcast network and a sensor network, possibly based on the IoT system (Lasi et al. 2014b). The aim of the smart city is basically to improve quality of life, safety for citizens and to provide energy efficiency, enabled, among the other instruments, by an efficient, safe and reliable transportation service Lu (2017). A proper definition is given by Roblek et al. (2016): "*city that comprises six factors in its development policy: smart economy, smart mobility, smart environment, smart people, smart living, and smart governance*".

Internet of Things

Internet of Things (IoT), is one of the enablers of the FIR and an important aspect considered in the Industry 4.0 framework. The IoT expansion in recent year is driven by increased availability of omnipresent, ever-shrinking, low-cost devices ubiquitous Internet connectivity and cloud computing. In general, IoT provides open and internet-based standards and solutions in collecting data from any plant, machine and devices (Georgakopoulos et al. 2016). Furthermore, according to Georgakopoulos et al. (2016), it is possible to affirm that the IoT, thanks to the internet protocol, allows heterogeneous devices, working with different algorithms, to communicate and interact with each other, going to an higher level of interconnection inside the production plant.

In addition to the improvements at manufacturing and productivity level, IoT is one of the enablers of the Individualized Production. In fact, IoT will change the relationship among customers, producers and suppliers, giving to each of these categories the possibility to be more involved in each stage of the production process (Lu 2017).

Going into a deeper level of analysis, it is possible to show what are the main area of incidence of the IoT ecosystem. The first point is a reliable, punctual measurement of the production KPIs. The automatic computation and visualization of KPI via IoT devices can highlight immediate opportunities for improvement; show alerts to the plant managers, in order to attribute precisely the responsibilities and the needs of the workers (Georgakopoulos et al. 2016). The second issue is related to the opportunity to embrace smart inventory policies, including electronically tagged products, to enable real-time tracking for all the items inside the plant. The IoT technologies, can be used to manage the internal logistics and to automatize this part of the production process (Georgakopoulos et al. 2016). Another important opportunity of the IoT solution is the possibility to use cameras and wearable object to help the worker to reach productivity targets and to provide support in the manual activities (Georgakopoulos et al. 2016; Strange and Zucchella 2017).

The IoT systems can be useful to realize the objective of the machine-to-machine (M2M) communication. This particular communication scheme, since requiring an high number of data, communicated in very short times, requires the implementation, on large scale of the new generation of connectivity networks, the 5G (Lu 2017).

Additive Manufacturing

In the recent years, Additive Manufacturing Technologies (AMTs), thanks to the progressive decrease of the costs of implementation, are becoming a widely used technology in manufacturing industry. As well as the above-mentioned technologies and systems, Additive Manufacturing is considered one of the pillars of the industry 4.0 development in the advanced countries. The term AMT is defined as “the process of joining materials to make objects from 3D model data, usually layer upon layer” (ASTM 2012 p.2). Belonging to the stream of the AMT, there are the 3D printers, that have been developed in the late 1960’s but, nowadays thanks to the decreasing costs of manufacturing of the printer themselves, are taking an important place in the production systems (Chen and Kamal 2016).

The use of 3D printers for manufacturing is becoming more relevant and it can be a disruption in the industries where the 3D printers are becoming more and more implemented. In particular, a disruption to the manufacturing system can result by the project undertaken by the UK project called RepRap (self-Replicating Rapid prototype), launched in 2004 (Bowyer 2014). The concept of the RepRap 3D printers is the fused-filament fabrication (FFF)[11], and the possibility to print other machines. In fact, the most recent versions of RepRap are able to print up to the 50% of another printer, deriving in a tremendous reduction of costs (Pearce 2016). An important feature of the 3D printers is given by the possibility to operate in open-source context, in which the innovations can come by a larger number of actors involved, and they are less hindered by the intellectual property issues (Wittbrodt et al. 2013). The innovations are faster than the ones of other manufacturing technologies, since the improvements are continuous in both the technologies of the 3D printers and the products that can be printed (Yu and Hang 2011; Chen and Kamal 2016).

For what concerns the large scale production systems, an extensive use of AMTs is considered relevant for the rubber and plastics manufacturing industries, in machinery industry, in the musical instruments production and in medical and dental application, specifically for the production of dental crowns, hearing air moulds, prosthetic limbs and rehab solutions (Laplume, Petersen, and Pearce 2016; Fratocchi 2018). Alongside with the already mentioned industries and product categories, in the future, as forecasted by Laplume et al. (2016), many other industries will be affected by the implementation of the AMTs; some of these could be: clothing, sunglasses, lighting instruments, furniture, bicycles, automotive (and parts), aerospace appliances. The implementation on a large scale of the AMTs could bring some benefits to the above-mentioned industries on many areas and many aspects, in terms of costs, customer value, and design and product innovation. The costs affected by the AMTs are basically the resources usage, inventory costs, production cost of the individual product, since

[11] Fused-filament fabrication is an Additive Manufacturing technique, having the same working principle of the fused-deposition modeling (FDM). The FDM is covered by trademark and it is a technique in which the 3D printer unwinds a plastic filament or metal wire from a coil and supplies material to produce a part (Taufik and Jain 2016).

no specific tools are required for different products, and the possibility of producing unique items (Fratocchi 2018). For what concerns the customer value, the AMTs allow to reach higher product functionality and a higher level of product customisation along with a better overall quality, in terms of both design and production (Fratocchi 2018). Finally, for design and product innovation are intended improvements as the possibility to produce complex and different shapes of products without affecting the time-to-market and the possibility to access new demand segments for products that must be tailor made (Khorram Niaki and Nonino 2017; Fratocchi 2018).

Other Technological components in the industry 4.0 framework

In the academic literature other technologies involved in the FIR are mentioned. Differently from the IoT and the CPS, these are not systemic implementation but just devices or parts of devices that could be the base for the FIR.

QR Codes

These systems are not new and not strictly related to the FIR, but can be useful in the automation of the production process, specially, in the internal logistic management (Stock and Seliger 2016).

RFID chips

As well as the QR codes, the Radio-Frequency Identification (RFID) systems can be a useful improvement in the internal logistic. The presence of the radio-frequency chip can be an important feature also for the external logistic. With respect to the QR codes, RFID chips can be an improvement, because the time required for the scanning is lower, so another step towards efficiency would be made (Stock and Seliger 2016; Lu 2017).

AGVs

The autonomous guidance vehicles (AGVs) are one of the technologies that would be implemented in the manufacturing plant adhering to the FIR. These instrument would be used for the movement of materials, WIPs or finished products into the plants, simplifying and automating the internal logistics (Stock and Seliger 2016). In order to have an efficiently working system based on AGVs, the plant must be based on a Cyber-Physical System and all the items that are transported must be equipped with the RFID chips, or, at least, QR codes, so the entire plant can manage the piece and make the whole production process from the first to the last step, totally automatized (Wan et al. 2016).

5G Connectivity

The Fifth generation of mobile technology is designed in order to meet the needs of the society of 2020. Therefore the features of this type of connection in terms of velocity of connection and amount of transferable data should provide high quality results (Strothers et al. 2004). The 5G networks will allow to have open access (multi-tenancy) infrastructure, that will reach speed of transfer in the order of GB/s (Siddiqui et al. 2016). Advanced countries are investing large amount of money in order to cover their areas with the networks (Stock and Seliger 2016). Initially the 5G connectivity will be available for the firms operating in the context of the FIR, given the peculiar features of the connectivity in terms of lower latency, ultra-high reliability, much higher connectivity density and higher mobility range (Strothers et al. 2004; Lu 2017). 5G is designed as an end-to-end system that includes all aspects of a network. 5G will operate in a highly heterogeneous environment characterized by the existence of multiple types of technologies, multi-layer networks, different devices and heterogeneous user interactions (Strothers et al. 2004).

1.2.3 Implications for managers and regulators

The large growth of the industry 4.0 has several and large implications for both managers and regulators of the countries in which there already is a large adoption of the technologies related to the FIR. Some opportunities can be highlighted in the adoption of these advanced technologies, as presented by (Schlaepfer, Koch, and Merkofer 2015):

- Increased competitiveness: the digitalisation will make the firm more effective on the value chains, both local and global;
- Easier adaptation to market changes: the features of industry 4.0 will involve the customers in the product design and also will give more flexibility to the company under analysis (Moeuf et al. 2018);

- Risk and fault reduction: thanks to more reliable technologies and the maintenance and the security supported by the Cyber-Physical Systems , the monitoring will be improved (Baheti and Gill 2011).
- Skilled workers and IT: the development of industry 4.0 will incentive the research for high-skilled workers and the creation of advanced IT system based on the synthesis of CPS and IoT;
- Use of currently growing technologies: all the smart technologies are the key for the transformation into the industry 4.0 and for the advancement of the FIR.

The implementation, at industry level, of the most important production management systems – namely, the CPS and IoT – can reshape completely the framework of the industry, starting from the technical production level up to the smart logistic management (Marques et al. 2017).

The CPS, working in a Smart Factory, can reveal itself to be very effective because those systems can entail a different regulation of the detection of the performances. The production systems become Reconfigurable Manufacturing Systems, in which the fixed structures and specification become more flexible, since components can be added or removed automatically, depending on their mechanical module interface (Abele et al. 2007). So, the presence of Cyber Physical System, can reduce the impact of the complexity of the organization, by increasing their flexibility, specifically, it will be possible to compensate a suboptimal configuration in one unit, with a bottleneck in another (Brettel et al. 2014). It is important to notice that this distributed planning can imply, in general, the risk of losing the optimization in the productive system. Thus, in order to manage the system in the best possible way it is necessary to adopt a global optimization strategy, that can be driven only by high level objectives, influencing the distributed production units (Brettel et al. 2014). Furthermore, thanks to the adoption of the new technologies, like ICT, IoT and CPS, it will be possible to facilitate the decentralization of the decision making (Lasi et al. 2014b). Decentralized decision-making is also made feasible by the presence of collaborative networks which consist of several autonomous entities, geographically dispersed and collaborating in order to achieve a common goal (Brettel et al. 2014). In the last periods, the trend is against the creation of long-standing, well-established and stable supply chains (Mertins et al. 2008).

These collaborative networks, need for a comprehensive approach, that is based on a six-step approach proposed by (Weiberg 1999), to ease the decision making:

- Ensure leadership and commitment: the existence of a facilitator, owning the process is very important to ensure the success. The figure in charge of this role, has to be an impartial and trustworthy entity, external to the network, or within the network, a different facilitator, depending on the goal of the project (Brettel et al. 2014);
- Frame the problem: specifying known objectives and constraints, with special emphasis on the assumption and the details;
- Develop evaluation models and formulate alternatives: formulated on the network vision, the alternatives must frame on the understanding of the issues requiring consideration;
- Collect meaningful and reliable data: all decision processes require collecting the right information, in terms of amount and tools of analysis (Delbecq and Van de Ven 1971);
- Evaluate alternatives and make the decision: several decision making tools can be implemented (Saaty 1980);
- Develop an implementation plan: the definition of an implementation plan allows to consider targets and constraints and project management issues.

In addition to the contents related to the ICT, the concept of smart factory is another enabler for the industry 4.0 development. The concept of Smart Factory is already presented by Radziwon et al. (2014) as a manufacturing solution that incorporates the concepts of adaptive production processes, automation, optimization, collaboration and dynamic organization. Furthermore, in order to give a better frame the Smart Factory into the FIR, it is important to mention the concepts of ubiquitous factory (Weiser 1991; Lucke et al. 2008). The new ubiquitous computing should provide real-time quality, resource, cost-advantage in comparison with the traditional production systems. In general, it is important to note how the new automation production systems are facilitating the transition towards the synchronization between real land digital world (Brettel et al. 2014). Furthermore, the technological infrastructure and processing capabilities are going to cooperate in forming a sort of "nervous system" within the factories (Raji 1994; Wadhwa 2012). These technologies will provide a huge impact on the factories, in both the daily operations and the business system, so enhancing the context awareness and the opportunities for better decisions (Brettel et al. 2014). Thus, an integrated connectivity system for the Smart Factory (Lucke et al. 2008) is associated to two perspectives in the resolution of problems (Brettel et al. 2014):

- Bottom-up perspective (emergence), it is based on the concept of small and simple systems aggregated in order to conduct complex tasks, as a decomposed structure;
- Top-down perspective (decomposition), based on the definition from the whole structure of the system management, to the lowest levels of complexity, at the real-world level.

1.3 Analysis of the technological factors influencing the reshoring decisions

Despite the RSD and the technological development related to Industry 4.0 initiatives are deeply covered by the academics, the literature about the interactions between the two phenomena, is scarce. In particular, the possible presence of causality among the two macro-topics has not been properly inspected, so far.

A certain degree of attention has been dedicated only to study the influence of specific technologies. Examples of this research stream include Alcácer, Cantwell, & Piscitello (2016) who inspected the effect of ICT's adoption on many industries, while Laplume et al. (2016) and Fratocchi (2018) who focused on 3D printing and Additive Manufacturing (AM).

The first area of analysis is the adoption of the advanced information-based technologies, such as ICT, IoT or Big Data. Alcácer et al. (2016) address to the role of ICTs the reshape of the Global Value Chains (GVCs) and the geographical distribution of the productive activity. In fact, it is important to highlight how the introduction of new technologies change over long periods the extent and the structure of all the Ownership (O), Location (L) and Internalization (I) advantages theorized by Dunning (1977).. In general, the presence of ICT creates more dispersed and interconnected production systems. This could entail a change in the meaning of the Ownership advantages. A firm operating in an interconnected system, indeed, could exploit not only its own competitive advantages, but also has use of the ones emerging in the structure and the various linkages of the system itself. (Cantwell and Piscitello 2015; Alcácer et al. 2016). The analysis on the Internalization aspects regards – especially with the influence of the ICT and the new technologies – the reshaping of the administration and control aspects in the MNE (Alcácer et al. 2016). The Internalization advantages may, in fact, arise when the capacity of control through administrative coordination overcomes the risks of competition (Alcácer et al. 2016). As regards the Location advantages, the usage of new technologies, in particular the extensive implementation of ICT, allows the MNEs to set their abroad divisions more freely. Always regarding the Location aspects, one of the side effects of the relocations is the creation of districts or global cities, so creating an external agglomeration effect (Alcácer et al. 2016). In fact, according to the same authors, the creation of global cities or industrial districts, can result into a more interconnected ecosystem based on more destinations for the firms.

Shifting the perspective to another technology, it is possible to note how the diffusion of new manufacturing techniques, like AM in general, or, more in particular, 3D printing, are going to affect the characteristics of the GVCs. Currently, China can be considered as the producer of most of the world's electronical components and it exports the largest share of clothing, toys and domestic appliances (WTO 2013). Laplume et al. (2016) investigate the modification of this equilibrium in the GVC framework through three determinants: factor cost determinants, presence of scale economies and factors impeding globalizations.

The analysis of the factor costs inspects the relative differences between the capital and the labour costs among countries. Figure 1.8 shows how the capital-cost differential between four advanced countries (USA, Germany, UK and Japan) and four emerging economies (China, India, Mexico, Brazil) is significantly lower than the labour cost differential for the same set of country (Laplume et al. 2016). This differential may justify the location of productive activities, especially the most capital-intensive ones (as AM is). In the economies where the large-scale adoption of the technology would be economically and technologically more feasible, the arbitrage for low wages would be less efficient for the exporting firm (Dicken 2014; Laplume et al. 2016). The effect is also confirmed by the EMS, as from data can be evinced that the most technologically advanced firms in the database are the most inclined to operate a RSD (Dachs and Cristoph 2014). Concerning the second determinant, the analysis on scale economies, it is worth a mention the reduction of the Minimum Efficient Technical Scales (METS)[12], obtained by the 3D printers. This would reduce the effectiveness of the concentration of production (Laplume et al. 2016). In fact, a lower METS, will eliminate the need of high demand to obtain the full plant utilisation, thus making unnecessary the concentration of the production in a single plant. The third GVC determinant is, in turn, based on three factors defined as those factors impeding globalization. The first one is the technological inseparability of the intermediate products. In this purpose, the 3D printing makes possible to shorten the value chain, by eliminating the phase of processing of the intermediate product. Items, in fact, are directly produced as finished products, starting from the raw material; thus eliminating the phases of transfer of the

[12] The concept of METS, introduced by Laplume et al. (2016), is an extension to the 3D printer context of the Minimum Efficient Scale definition, represented by the minimum quantity that is possible to produce in order to minimize the average production costs.

intermediates and the assembly stage (Laplume et al. 2016). Always considered by the authors as factors impeding globalization, transportation costs and trade barriers are significantly affected by the adoption of AM production techniques. The transportation costs are lowered in general, thanks to the lowering of the METS (and the consequent decentralization of the production sites) that will decrease also the quantities of finished products to transfer from the production facility to the consumer (Laplume et al. 2016; Strange and Zucchella 2017).

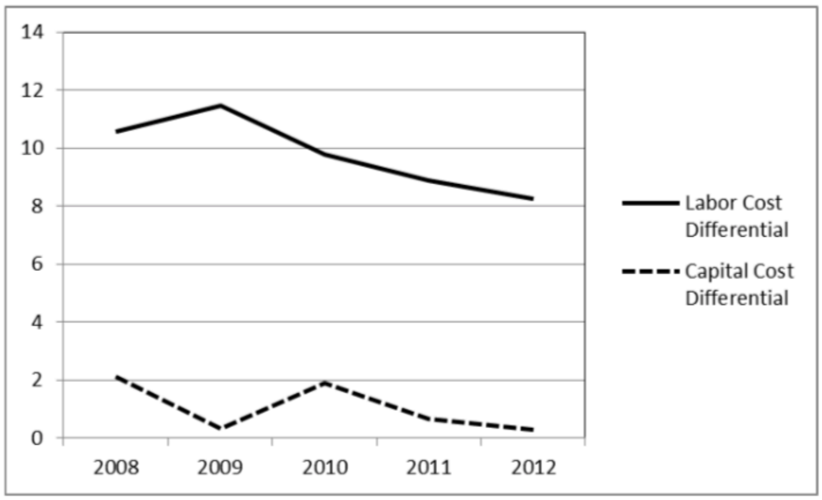

Figure 1.8 - Trend in labour cost and Capital-cost differentials 2008-2012. Source: Laplume et al. (2016)

Although the tariffs on finished products are progressively increasing in the recent years (WTO 2015), 3D printing allows to bypass this issue, because they require trade to be undertaken only for raw materials. Indeed, tariffs on raw materials are significantly lower than the ones on finished products. Thus, the product can be produced directly in the country where the consumer is (Laplume et al. 2016). In general, it is possible to conclude that the adoption of AM may have a simplifying effect along GVCs, referring to the distinct activities and the relative geographical dispersion of them. This is conceptualized by Strange and Zucchella (2017) according to which, the possibility to implement on large scale the AM technologies, will also reduce the number of the interactions among all the actors. In this argument, a negative correlation can be identified between the adoption of AM technologies and the country level of the GVC participation, enforcing the theoretical hypotheses with an empirical evidence (Buonafede et al. 2018). Furthermore, Strange and Zucchella (2017) suggest the possibility that a wide implementation of the AM technologies all over the world could imply the creation of 3D printing supercentres[13] in co-located with traditional manufacturing facilities. The establishment of these plants would happen, as for other plants based on the 3D printing, in locations closer to the final customers.

Shifting the attention from the general GVCs overview to the more particular reshoring related topic, the adoption of AM can be individuated as a motivation to undertake a RHC for some firms recorded in the Uni-CLUB MoRe dataset (Barbieri et al. 2018; Fratocchi 2018). In the cited dataset, 11 companies referred to the usage of AM as a direct motivation for the reshoring operation. Other firms, instead, did not cite explicitly AM, but rather other reasons that can be considered as benefits for the implementation of 3D printing production techniques (Fratocchi 2018). Among these reasons, the most cited ones are the total cost of ownership, divided into the components of reduction of inventory costs, lower production costs for small batches and reduced resources (energy, water and other natural resources). Furthermore, other important reasons for reshoring, possibly resulting from the implementation of AM, are the higher product functionalities and customization, an increase of the "design freedom" (Khorram Niaki and Nonino, 2017). Again, Fratocchi (2018) and Laplume et al. (2016) cite as improvements derived by the adoption of AM technologies, the possibility to manufacture unique items jointly with the reduction of the minimum size lot, as a direct consequence of the METS reduction.

Since, in the outlined context, labour cost differentials lost their importance (Laplume et al. 2016), another important role can be played by the implementation of Robotics in production. In fact, the decrease of the cost of implementation, together with an overall increase of efficiency, gave a new push to the diffusion of this productive system (Sirkin, H. L., Zinser, M., & Rose 2015). The ease of implementation and use of robotics technologies, can be considered a driver for the reshoring of productive technologies, in particular for the RHC (Albertoni et al. 2015). This can be interpreted also as a response to the progressive shrinking of the labour cost differentials between advanced and developing countries (BCG 2013; Strange and Zucchella 2017) and to the upsurge of protectionist measures around the world (WTO 2016). On this last point, however, it should be said that the turn to robotics

[13] A 3D printing supercentre is defined as a "specialist facility that undertakes low-volume, customised production" (Strange and Zucchella 2017). This type of plants will be used by the manufacturing firms in order to expand their productive range to uncommon and less demanded products.

and, in general, more automatized ways of production in developed countries does not imply strong gains for the labour force when the RHC occurs. In fact, even if the demand for high-skilled labour will grow, the positions with the lowest wages will be substituted by the robots (Strange and Zucchella 2017).

Recently, the technological improvements described above (such as, IoT, AM and CPS) caught a growing attention by policymakers, eventually resulting in the upsurge of many Industry 4.0 initiative worldwide. Some of the advanced countries launched these programs with the aim of boosting their economies, with a particular attention to the manufacturing sectors. Notwithstanding, these policy initiatives are increasingly been seen as instruments in the attempt to repatriate activities of firms that had previously offshored their production abroad (Lasi et al. 2014b; Schlaepfer et al. 2015; Deloitte 2018).

As mentioned above, the extant literature of reshoring did not investigate explicitly the influence on the reshoring phenomena implied by the whole Industry 4.0 stream. Amongst most recent contributions trying to summarize the effects of a comprehensive set of Industry 4.0 technologies and associated initiatives there is the work by Müller, Dotzauer, and Voigt (2017). The authors, by means of a survey on 50 German firms, found a relationship between the launch of the Industry 4.0 initiative in Germany and the choice to relocate back the production activities of the firms themselves. The empirical research conducted, sustained three claims, valid for the German firms under analysis:

- Industry 4.0 will play a role in bringing back production to Germany;
- Industry 4.0 will play a role in setting up new production facilities in Germany;
- Industry 4.0 will play a role in switching from foreign to German suppliers (Müller et al. 2017).

The companies in the survey also indicated some specific drivers for reshoring, that could be related to the Industry 4.0 policy, the top 5 for the companies under analysis are:

- Improvement of innovation skills;
- Political incentives and government support;
- New technologies implementation;
- Faster time to market,

- Reduction of the communication and coordination costs.

The categories indicated by the German firms undertaking the survey are basically largely related to the innovation field and to research and development (R&D) activities (Müller et al. 2017) than the ones related to poor quality production, flexibility and lead times (Kinkel 2012; Fratocchi et al. 2016).

Since the diffusion of Industry 4.0, in Germany, suggests being a general factor triggering the repatriation of manufacturing tasks, the research conducted in this work will proceed by investigating the extent of their impact on RSD (both RHC and RTC). Overall, following previous contribution by Barbieri et al. (2018), RSD events will be analysed considering the relationship with macroeconomic variables, legislative factors and the adoption of Industry 4.0-based policies by central governments. Furthermore, an analysis on the level of innovation of the company will be conducted, in order to verify if the most innovative companies have a different propensity to relocate their productive activities, in the context of Industry 4.0 initiatives (Alcácer et al. 2016).

Once the theoretical implications are presented. A research question can be formalised.

What is the impact of the FIR on the propensity of the offshoring firms to undertake a RSD, in terms of either RHC or RTC?

Chapter 2: Data Analysis

2.1 Analysis on the data in the field of Back Reshoring

The analysis of the back-reshoring phenomenon is based on data from the European Restructuring Monitor (ERM) which provides information related to several companies that have relocated part of their activities in a different country. The data about restructuring events for each company is retrieved and cross-checked using several secondary sources such as international business literature, consulting companies' white papers, and many others (Fratocchi, Barbieri, et al. 2013). The sub-sample of the database used in this work focuses only on relocation operations. It contains 535 evidences of RSD and, for each of them, variables regarding the location of the headquarters of the company, the "abandoned" host country (i.e., "host 1") and the final destination chosen (i.e., "host 2") are reported. Moreover, other information indicating the structure, the industry, the declared motivations for the undertaken reshoring strategy and the year of implementation are gathered.

A first view of the data helps to highlight the number of operations in the years under investigation (i.e., 2002-2015), with the distinction between RHC and RTC.

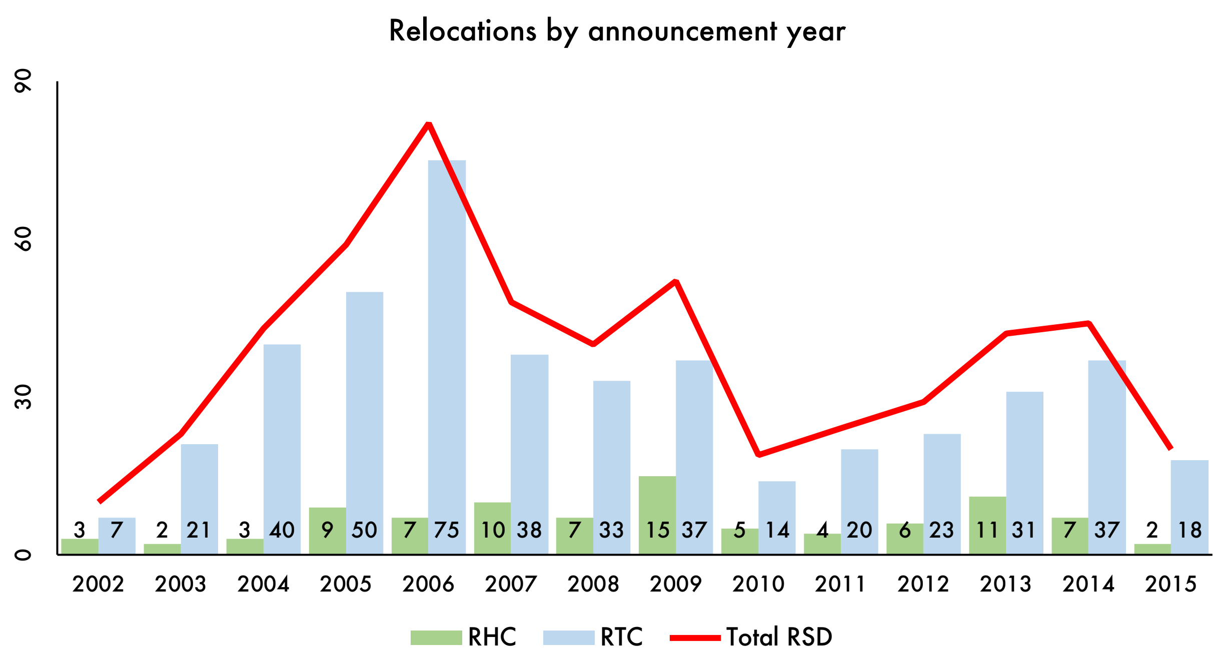

Figure 2.1 - Reshoring activities with distinction among RTC and RHC. Source: Barbieri et al. (2018)

Figure 2.1 shows how the relocation phenomenon is oriented on the RTC. It is also possible to notice how the 2004 expansion of the EU gave a strong push to the number of total relocations, especially towards the eastern European countries. This strong increase might be attributed to the reduction of the barriers to export on several manufacturing goods. The number of RTC significantly decreases in 2010, probably as a consequence of the 2007-2008 financial crisis. For what concerns the RHC, it is possible to observe that the peaking value occurs in 2009, right after the explosion of the financial crisis, giving partial support to the tendency of the firms to concentrate the production in a single country, with the attempt to saturate the production capacity of the plant.

Changing the dimension of analysis, it is possible to make a distinction on the relocation activities on a geographical base. In particular, the most active countries of origin of the relocation activities are shown (Figure 2.2). For the reported countries it is also shown an internal distinction to point out the share of companies that have undertaken a RTC or an RHC. British, French and German firms are the most inclined in the RSD, and more specifically, firms from the United Kingdom and from France are the most active in RTC. On the other hand, French firms are as well among the most active in RHC, together with German, Swedish and Italian ones.

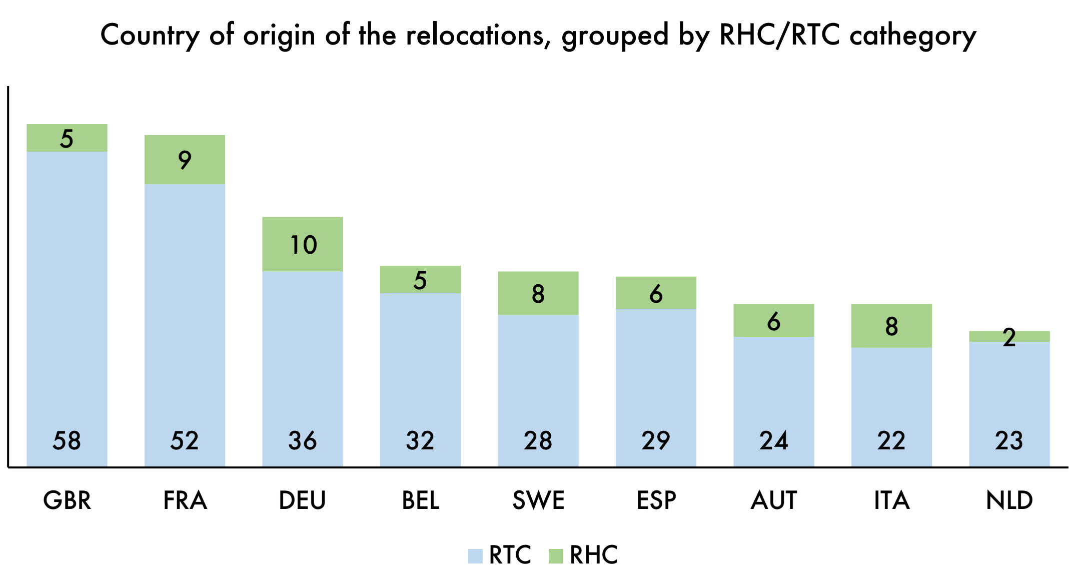

Figure 2.2 - Most frequent origin for RSD, divided by RTC and RHC.
Source: ERM dataset

In addition to the country of origin of the RSD, it is of paramount importance to describe the country of destination of the relocations. The data are described in Figure 2.3, where

Poland figures as an important destination for reshoring, and all the operations related with the country are, in facts, of RTC-type. The only exception is represented by the Polish firm Boryszew, which repatriated its operation from Germany to Poland in 2014. Among the most frequent destinations for RTC, Romania, Hungary, Czech Republic and Slovakia feature as leading countries, also showing an almost absolute absence of the RHC. As presented in the figure, Germany is a relevant destination for both RTC and RHC operations: notwithstanding, concerning back-reshoring events, the country is the most frequent one in absolute terms.

Other representative countries are France, United Kingdom and Italy, represented by an equal number of the two categories of RSD.

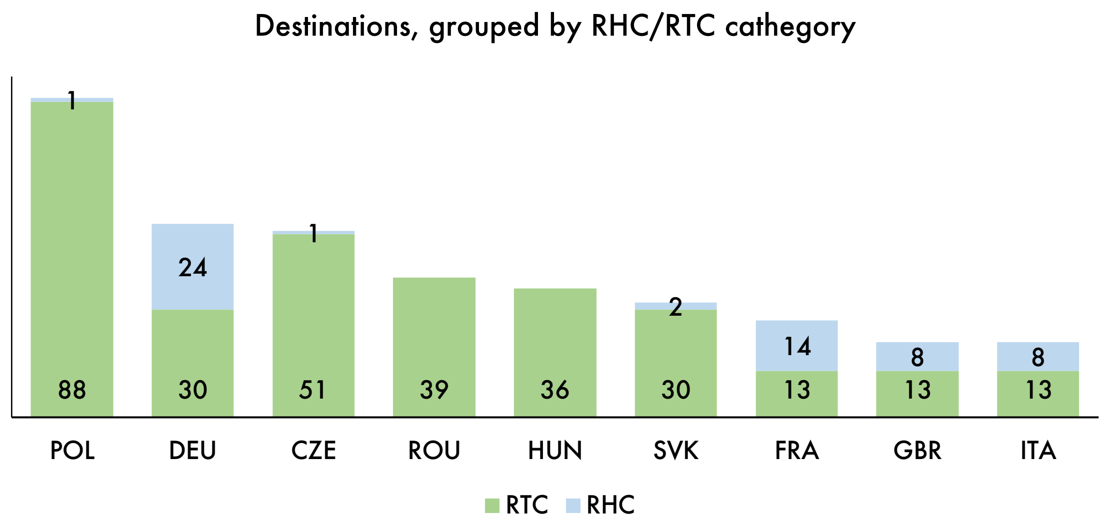

Figure 2.3 - Most frequent destinations for RSD, divided by RTC and RHC.
Source: ERM dataset

Shifting the perspective from the country level to the single firm level, it is possible to distinguish different behavioural patterns regarding the different typologies of RSD. In the dataset, there are some companies that have been recorded more than once; hence, it is possible to gather them in a table and perform a comparative analysis of the destinations chosen by these companies. Specifically, the three most selected countries for a RSD are shown. From this perspective, it is possible to recall the different incidence of the RTC with respect to the RHC on the total number of RSD and the respective most preferred destination (Table 2.1). As it emerges from the data, Delphi, Kraft Foods and Philips have undertaken only RTC-type relocations, while Unilever and Electrolux only one RHC. The countries marked with a star, in the table, are the Home country for the firm in the row, so for these firms, a RHC took place. The average preferred destination for the firms in the table is Poland, ranking first for seven firms out of the first eight. Another important destination is Hungary, resulting the preferred destination for Delphi and Bosch, while it is the second for Philips. Other outstanding countries are represented by Slovakia, Romania and Czech Republic. As mentioned in the previous sections, an important role has been played by the Eastern expansion of the European Union in 2004 and 2007. In fact, Hungary, Poland and Slovakia are part of EU since 2004 and Romania entered in the EU in 2007. For what concerns Unilever and Electrolux, the heterogeneity in number of the destinations is worth a mention; the two firms, in fact, recorded respectively nine and seven different destinations, together with Poland and the respective home country. Looking at the firms that are recorded for the larger number of relocations in their home countries, there is a peculiarity. The larger part of them have indeed performed only RHC or, in some other cases, the large majority of their operations in this way. The most active in this perspective is Alstom, recording three RHC out of the four RSD in the dataset. Volkswagen, Arla Foods, Takao Europe, Thyssenkrupp, Renault and Lonza instead, performed two RSD and all of them in their home country.

Firm	**TOT**	**RTC**	**RHC**	**Country 1**		**Country 2**		**Country 3**	
Delphi	13	13	0	Poland	3	Hungary	3	Romania	2
Kraft Foods	13	13	0	Poland	5	Slovakia	2	Other (6)	1
Unilever	10	9	1	Poland	3	Other (7)	1	UK*	1
Electrolux	9	8	1	Poland	3	Other (5)	1	Sweden*	1
Philips	8	8	0	Poland	4	Hungary	2	Other (2)	1
Bosch	7	6	1	Hungary	3	Romania	2	Germany*	1
Procter & Gamble	5	5	0	Poland	2	*East EU*	2	Russia	1
TRW Automotive	5	5	0	Poland	3	Czech Republic	2		

Table 2.1 - Relocations of the most active firms and preferred destinations.
Source: ERM. Own Elaboration.

Furthermore, other 42 companies in the dataset, performed only one RSD, directed to the own home country (i.e., an RHC). Among these companies there are also some large multinationals: the Italian multinational company Fiat and the German multinationals BASF and Bayer, just to mention a few.

2.2 Data analysis on the technological improvements

2.2.1 National Initiatives on Industry 4.0

In order to determine what are the possible drivers of attractiveness for a country, it is necessary to recall the idea by Arlbjørn and Mikkelsen (2014). According to the authors, a firm will be more inclined to relocate its productive activity in a country where there is the possibility to obtain more advanced and reliable technology. This rationale is of fundamental importance to the analysis carried out in this dissertation; hence, hereafter, I present a detailed picture of the Industry 4.0-based initiatives conducted in the countries included in the sample.

Starting from the 2011 launch in Germany of the "Industrie 4.0" program, a large number of other countries tried to set similar initiatives in order to boost productivity and innovation in the manufacturing sector. The Industry 4.0 initiatives launched by the different governments present different characteristics and structure, in terms of area of impact of the technologies or, more basically, in the funding scheme adopted. Some of these initiatives are also supported by supranational entities. The European Union, in particular, promoted the launch of other typologies of programs, not only at the country level, but also at the regional level. These programs are intended in line with the Economic and Cohesion policies of the European Commission (EU 2018a). Given also the stimulus coming from the EU, all the countries belonging to the Union have launched their own Industry 4.0 policies during the last few years. Figure 2.4 reports a general overview of the sample countries that have adopted a policy aimed at promoting the development of Industry 4.0 technologies[14]. Obviously, Germany (in red) stands out, given its early and pioneering decision of 2011. Right after Germany, in the following year, Sweden and United States[15] became early followers, launching their own programs in 2012. The years 2013 and 2014 represent two transition

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[14] The countries in the dark grey did not undertake an explicit and defined Industry 4.0-oriented policy, but are still included in the graphic, since these ones are country of origin or destinations in the dataset of reshoring firms.

[15] The United States, in 2012, established a large network of cooperating institutes under the name of Manufacturing USA, with the ambitious purpose of fostering the productivity of the American firms and the attractiveness of the country in order to create new jobs in the manufacturing sector, deeply affected by the 2007-2008 economic crisis (USA 2011).

years, with the adoption of policy initiatives in the United Kingdom and Austria, confirming the innovation propensity and the ever-increasing attention towards the FIR. During the years 2015, 2016 and 2017 a large number of countries, including developing economies like Indonesia and Malaysia as well as advanced economies like France (with the "Industrie du Futur" plan) and Italy (that launched in 2017, the "Piano Nazionale Industria 4.0") followed in the adoption of targeted initiatives. Amongst late introducers, in temporary order there are China, Romania and Portugal, only launching their Industry 4.0 plans in 2018. It is worth mentioning the case of Poland where, in 2017, an ambitious Industry 4.0 plan has been launched under the name of "Moraviewcki Plan"[16].

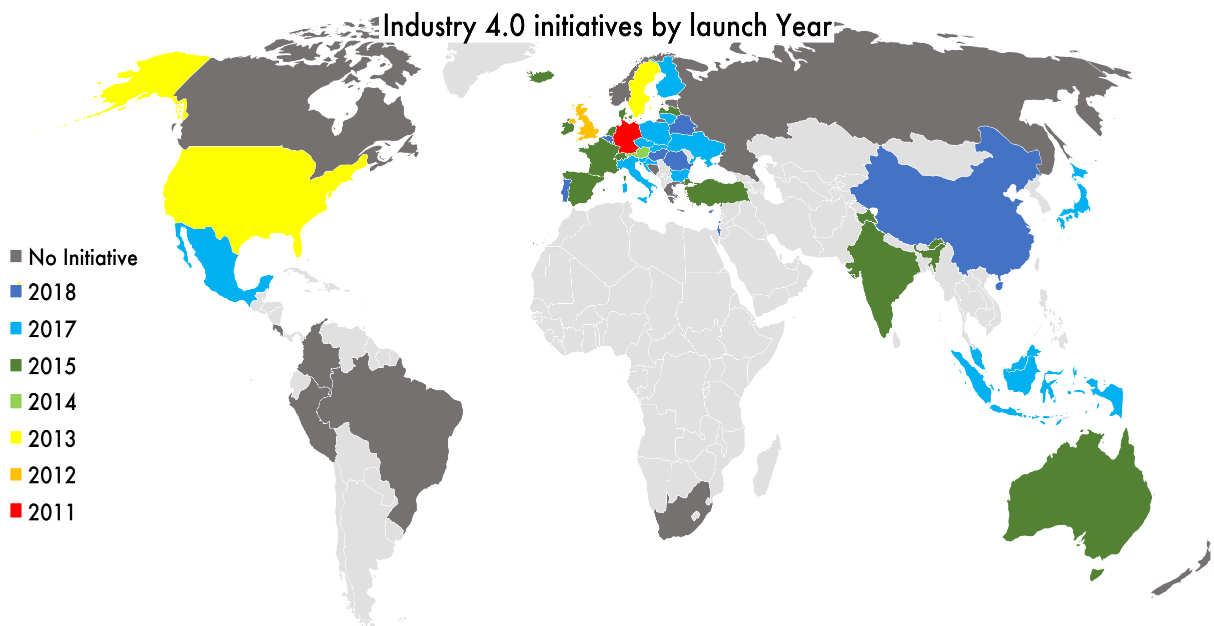

Figure 2.4 - Diffusion of the Industry 4.0 Initiatives, by year of adoption. Own elaboration

Amongst late introducers, in temporary order there are China, Romania and Portugal, only launching their Industry 4.0 plans in 2018. In fact, for these initiatives there are no clear information on the area of technological focus or the extent and nature of the investments.

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[16] The "Moraviecki Plan" is a series of public investments, in many sectors, from the support for the families to the push of the public investments in manufacturing and construction. The plan takes the name of the former Polish Minister of Economic Development and now prime minister Mateusz Morawiecki and expects an increase of the public expense up to 2 trillion of PLN (USD 264 billion) (Harper 2016).

Going into a deeper level of analysis, it is possible to distinguish the different funding scheme of each policy among the countries that have adopted an Industry 4.0 policy. Figure 2.4 shows those countries where there are initiatives related to the FIR and the essential functioning of their funding scheme. Two clusters of countries can be distinguished, one with the central government authority – in many cases, the Ministry of economic development – as a sole funder, and the other one with the government providing support and a certain amount of financing jointly with associations of firms, privately providing funding. Countries[17] belonging to the first category (in Figure 2.5 marked as "public") provide financial support in the form of subsidies and/or dedicated financing schemes to those firms adopting the advanced technologies for producing smart products and goods in advanced production systems[18]. Among these countries the ones that worth a mention are Germany and Italy for their structured and government-based plans named "Industrie 4.0" and "Piano Nazionale Industria 4.0", respectively. Furthermore, it is important to mention the presence of China in the public-based cluster, partially confirming the nature of its command and control economy.

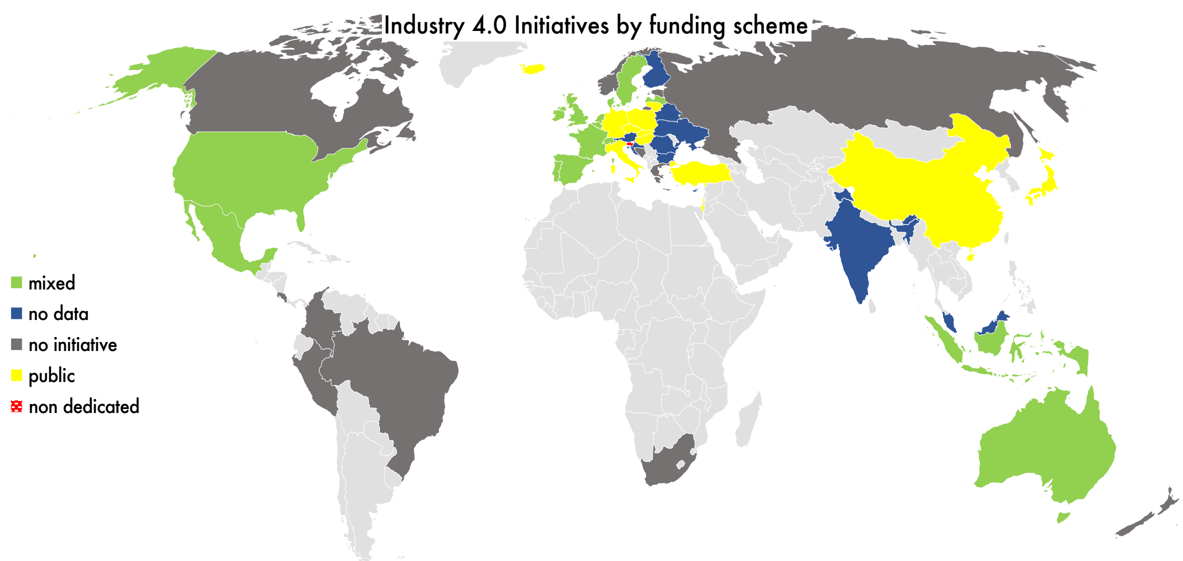

Figure 2.5 - Diffusion in the world of the Industry 4.0 initiative, by funding scheme. Own elaboration

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[17] As for Figure 2.4, also in Figure 2.5 I included all the countries for which at least one reshoring initiative is recorded, whether the country is origin or destination of the transfer. The countries marked in grey are the ones for which no Industry 4.0 program is defined. For the ones in blue, instead, no data on the funding or expenses of the government have been retrieved.

[18] As advanced production systems are referred aforementioned IoT, CPS or 3D printing.

The last cluster of countries, the "mixed" financing method one, encompasses, notably, the United States. This because of the presence of the Manufacturing USA consortium of firms and universities, self-organised in retrieving the funding and in providing firms respecting certain criteria with the opportunity to invest in the most advanced technologies for their manufacturing processes. In particular, the association of firms called "America Makes" is totally focused in providing technical support and managing loans for those firms undertaking projects related to AM and 3D printing (Deloitte 2017). Two other important countries in the mixed cluster are France, with the initiative "Industrie du Futur"[19] and United Kingdom, with the "UK Manufacturing Catapult"[20]. Countries marked in blue ("no data") are the ones for which there is an Industry 4.0 initiative, but it has not been possible to retrieve clear information on the structure of the program and the related funding model. For some of these countries, the reason of this lack of clear data has to be ascribed to the fact that the initiative has been promoted only in 2018. In some cases, such as for Slovenia or Romania, the initiative is still in the programming phase.

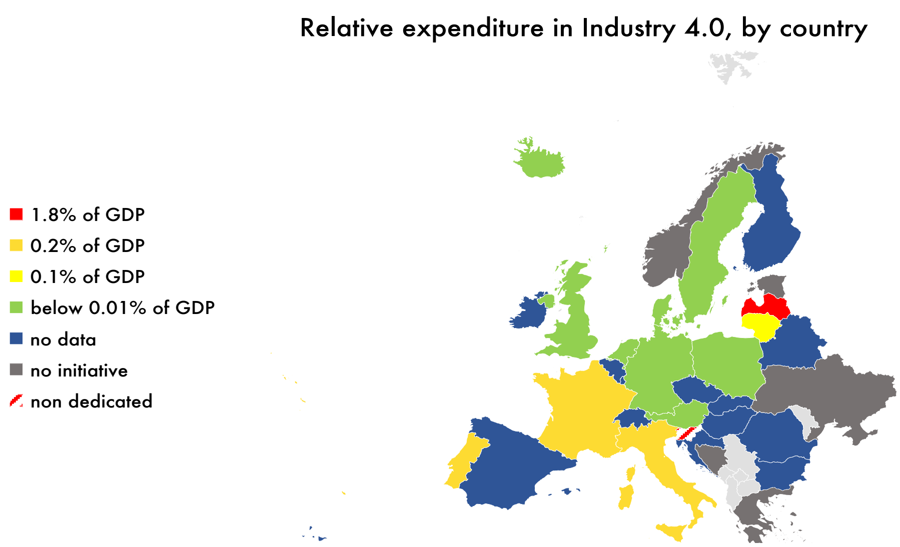

Figure 2.6 - Amount of investments in Industry 4.0 by country divided for the GDP at PPP in 2017.

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[19] The "Industrie du Futur" inititative, is a program aimed at modernising the French industry, by anticipating the digital transformations of the economy. The initiative is based on five pillars: Expand the technological offer; support SMEs; provide the training to develop the new skills needed; promote the plan abroad; support international and cooperation standards. Source: http://www.industrie-dufutur.org

[20] The "UK Manufacturing Catapult" is an association of firms and research centers. The general aim of the initiative is to improve the competitiveness of UK businesses by providing novel and effective technology solutions across the manufacturing sector. It is based on public and private funding provided to the firms adhering to the program. Source https://hvm.catapult.org.uk

For some countries it has also been possible to collect information on the amount of investments in Industry 4.0 programs. Hence, for these sub-sample of countries it is possible to make a comparison based on the effective expenditure. Figure 2.6 reports this insight for the European countries[21]. In order to have a more homogeneous and comparable measure of the expenditures, the figures were first converted in USD, and then normalised by the GDP (at Purchasing Power Parity conditions) of each country, respectively.

As can be seen on the map, Portugal, France and Italy, can be related, since the central government expended an amount around the 0.2% of the GDP. Among these countries, a similarity can be tracked between Portugal and France, because of the common year of launch of the national initiative. Italy, instead, started its program afterwards, but with the same pattern of expense of the other two countries. In green I represented the countries that spent an amount lower than the 0.01%. Among these countries it is important to mention Germany and United Kingdom, for which the figure is small compared to their large nominal GDP, and Poland, because of the investments of the ambitious "Moraviecki Plan" are still at the beginning phase. Furthermore, the similarities between UK and Germany consist also in the date of launch of the initiative. The two countries, in fact, have been the first in Europe to start a structured initiative for the promotion of Industry 4.0. A notable exception is represented by Latvia, for which the total expense in the Industry 4.0 reached in 2017 the 1.8% of the nominal GDP; this result is determined by the bold program of investment that the Baltic republic launched in 2015, compared to the smaller figure of GDP with respect to all the other European economies.

[21] Only for the European countries, has been doable the retrieval of clear and punctual data about the public investment in the Industry 4.0 programs.

2.2.2 Data analysis on the Patents relative to the new technologies

A crucial component of the work carried out in this analysis is related to the provision of a closer view of the technological advancements for countries and firms impacted by relocation decisions. As suggested by Arlbjørn and Mikkelsen (2014), the level of innovation of a country is an attractive factor for a firm that is willing to relocate its productive activity. In addition to this, the innovative content has to be framed into the field of the new production technologies, encompassed by the FIR (Lasi et al. 2014b; Lu 2017) / Industry 4.0 (Stock and Seliger 2016; Deloitte 2018).

Recently, the concept of the FIR has also gathered the attention of the central regulators for the technological development in Europe: the European Patent Office (EPO). In fact, in 2017, the authority released a report encompassing all the technologies considered enablers for the Industry 4.0 diffusion and their relative patents (EPO 2017). The report published by the EPO is based on a four-step procedure: first, a mapping of all the patent classification, in order to extract the ones complying with the Industry 4.0 parameters. Second, the identification of all the patent application of the technologies identified; finally, a classification of the application by applicants and inventor is performed (EPO 2017). Starting from the information provided by EPO's report, a detailed inspection on the diffusion of Industry 4.0 technologies has been executed, in order to obtain relevant data about the degree of innovation of firms and countries analysed in the ERM dataset.

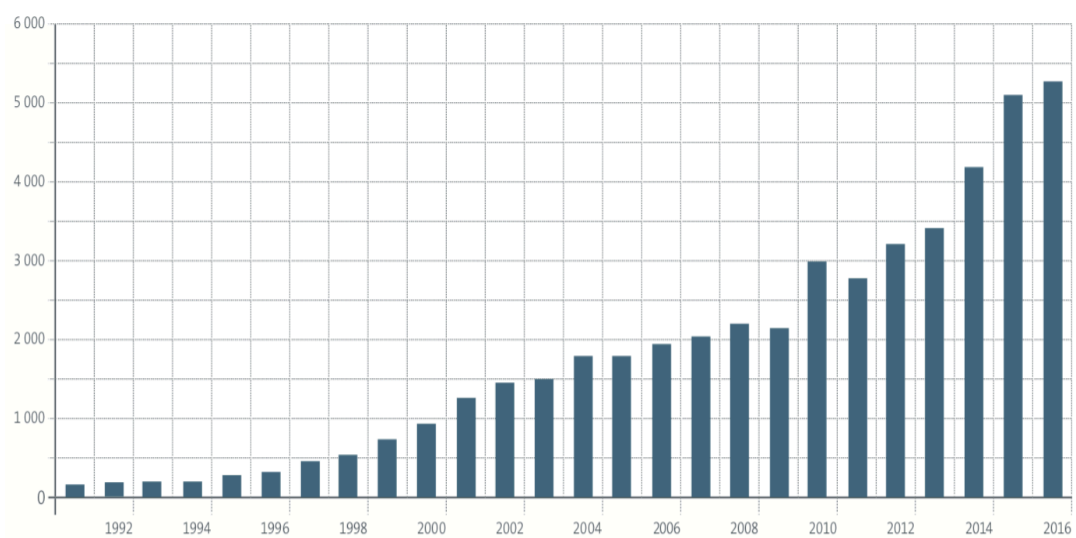

Figure 2.7 - Number of total patents in the field of the "Fourth Industrial Revolution", by year. Source: EPO (2017)

As Figure 2.7 suggests, in the recent years, a growing number of patents has been registered in the EPO database. The figure records all the patent application to the European Patent Register in the timespan from 1991 to 2016 that the EPO considers relative to the FIR, by all the firms or individuals. The last two recorded years, 2015 and 2016 witness a total number of patents relative to the Industry 4.0, above the number of 5,000 (EPO 2017).

An aspect to which the EPO, in its report, reserved particular attention is the number of patents applied in the field of AM. As shown in the literature review section, these manufacturing technologies are considered an important pillar of the Industry 4.0, to whom some academics attribute a crucial role for the reshaping of the GVCs (Laplume et al. 2016; Buonafede et al. 2018) . Figure 2.8 highlights the continuous growth in the application of patents relative to AM. The graph presents the trend associated with two distinct set of patent data: the first one represents the whole stream of patents categorized in the field of the AM, for which the total number rose over 500 applications in 2015. The other line in the graph represents a subset of applications in the field of AM and belongs also to the FIR parameters of the EPO report. The EPO, in fact, does not considers all the AM technologies as enablers for the FIR, but only the subset of them that respects particular requisites in terms of digitisation and networking.

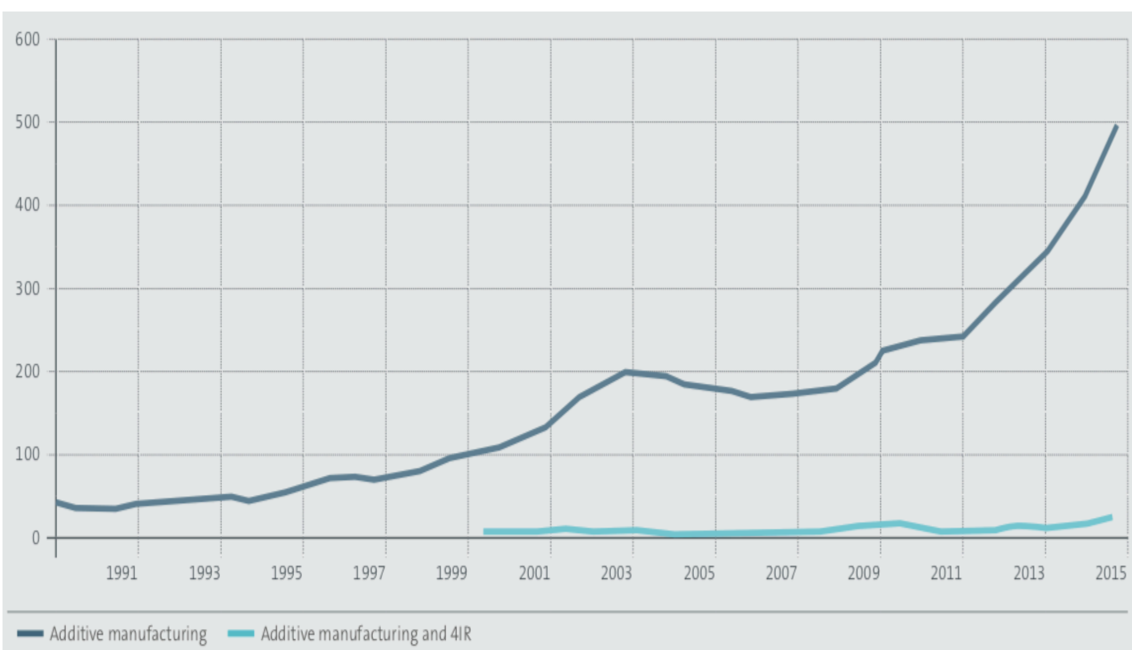

Figure 2.8 - Patent applications for additive manufacturing (1990-2015). Source: EPO (2017)

Together with the statistical data and the conceptual information regarding the knowledge-development around Industry 4.0, the report of the EPO contains a fully comprehensive list of all the patents-codes relative to the FIR. In order to obtain significant data about the firms regarding their propensity to adopt the new technologies, a research has been conducted on the Global Patent Index (GPI) software. This instrument supports the running of complex queries, containing large numbers of codes and firms. Since the codes contained in the EPO report are expressed according to the Cooperative Patent Classification (CPC)[22] that is not supported by the GPI, a conversion has been necessary to extract the IPC[23] codes. The IPC standard, in fact, is recognized by the GPI for the search of the patents. The initial list, responding to the CPC standard, is made by 260,000 codes. Since the IPC is a less sophisticated standard, for each IPC code more than one CPC code may correspond. Thus, the number of IPC codes amounted to 2,871. Once the patent codes are defined, multiple queries were run on the system of the GPI database, searching for all the companies in the dataset, the number of granted patent for the relocation year[24].

Given the large number of codes belonging to the EPO parameters for 4IR, I have conducted an analysis on the most represented categories of patents. In order to have a representative division of the groups, the patents have been categorized according to their IPC class, by truncating the codes at the third character. Table 2.2 represents the first IPC classes respecting the 4IR parameters of the EPO and their definition. The definition of each class is given by the "class index", namely, an informative summary giving a broad idea of the content of the class[25].

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[22] The Cooperative Patent Classification is a standard jointly developed by the EPO and the US Patent Office, in force from 1 January 2013.

[23] The International Patent Classification is a standard relative to the patents, introduced in 1968, that comprehends all the applications and the granted patents in the European Patent Office. The code is based on up to eight alphanumeric characters: the first letter indicating the *section*, the second/third, a number indicating the *class*, the fourth letter indicating the *subclass*, a number indicating the *main group* and finally, after a front slash, the whole IPC Code.

[24] See Annex 2 for the complete definition of the queries on the Global Patent Index.

[25] For a thorough clarification of the classes, see WIPO and World Intellectual Property Organization (2015).

IPC Class	Count	Share	Definition
H04	478	16.7%	Electric Communication Technique
G06	419	14.6%	Computing, Calculating, Counting
D06	307	10.7%	Treatment of Textiles or the like
B60	303	10.6%	Vehicles in General

Table 2.2 - Largest classes of patent codes in FIR. Source: EPO (2017). Own elaboration.

The class of codes with the highest frequency in the EPO report are, expectably, the ones related to electric communication techniques and to computing, calculating and counting. These first two classes refer items that can be considered as enablers for the IoT technologies, to be embedded in the production systems and to the control mechanism, such as the CPS systems. The third representative class refers to particular treatment of materials with advanced materials and non-conventional techniques, like the usage of halogenated aldehydes, alcohols, hydrocarbons, compounds containing oxygen. To refer to the class B60, defined by IPC "vehicles in general", it is necessary to give a closer look to the most frequent main group[26]. The most frequent main groups for the B60 class are the ones indicating systems of control for the driving of road vehicles (WIPO and World Intellectual Property Organization 2015). The other classes of patent codes, not reported in the table, have occurrences below the 10%, and most of them refer to electronic educational appliances, measuring and testing appliances, instruments for the control of industrial machines, visual and audible alarms and traffic controls and also electronic musical instruments[27].

Once the analysis of all the patents has been completed, the data were cross-checked joining the dimension of the patents and the one regarding the firms that recorded at least one RSD in the timespan 2002-2015. The data have been gathered following the procedure described above.

[26] The *main group* of the IPC standard is defined by the first five or six alphanumeric characters of the IPC code.

[27] For the complete list of the IPC codes included in the EPO report for the FIR, Annex 1.

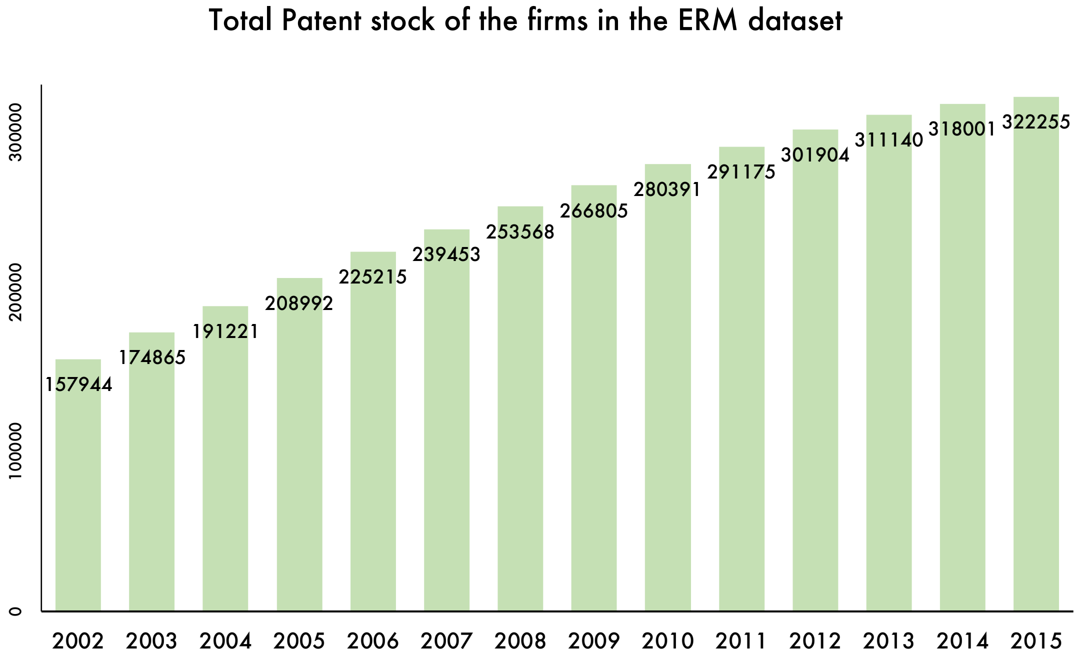

Figure 2.9 - Total Amount of the Patent in FIR for the ERM firms. Own elaboraton.

The histogram presented in Figure 2.9 shows the cumulative amount of the patents from 2002 to 2015; the initial value has been computed searching all the patent codes previous to the year 2002, while the following years are computed by adding the punctual value of the granted patent in the previous year. From the graph a clear increasing trend of the number of patents can be evinced, certifying an overall effort by the firms in the database towards innovation and an openness to the newest and more advanced technologies represented by the FIR patents. In general, in the latest year a decrease of the slope of the curves can be noticed. The reason for this peculiarity can be explained by the structure of the data researched. In fact, in the GPI it has been possible to search the patent for their priority date; in so doing, requesting only the granted patents may reduce the punctual value for the latest years, because of the technical times for granting the by the EPO.

In order to broaden the field of investigation, the countries of belonging of the most innovative firms can be determined. The sum of the cumulative patents grouped by home country is shown in Figure 2.10. In the graph I represented the first four home countries for the firms under analysis, according to the cumulative number of granted patents.

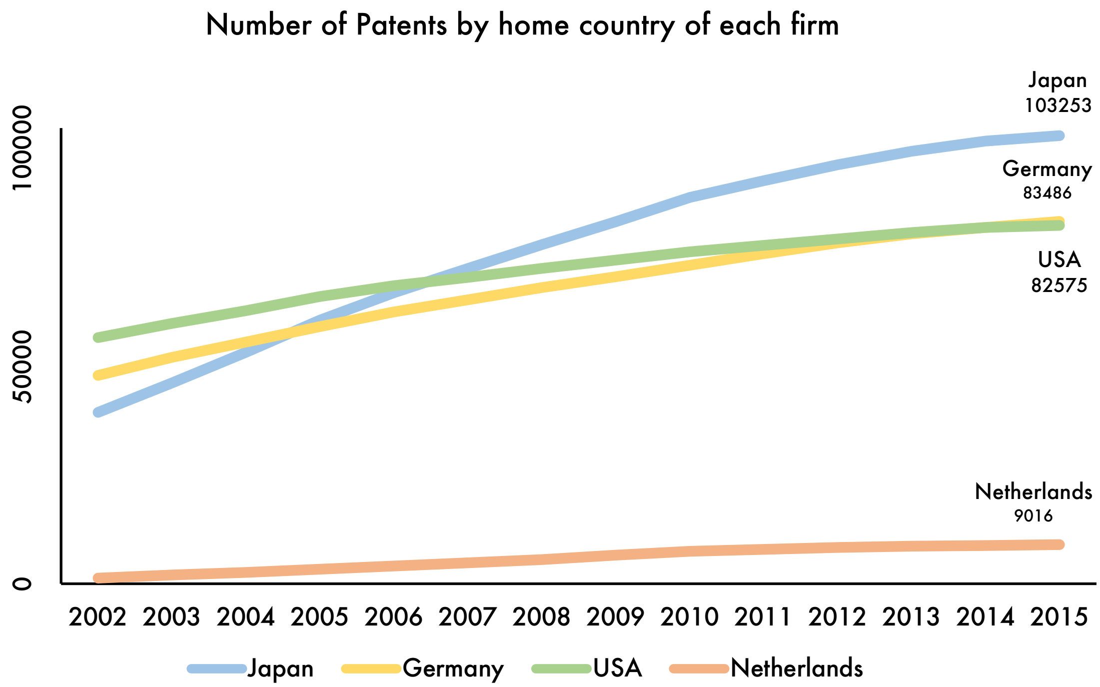

Figure 2.10 - Number of Patents applied by the firms, grouped by home country of each firm. Source: GPI. Own elaboration.

The general trend is the same than the graph comprehending the firms altogether, but in this case, it emerges how the American firms, although being very innovative, have been reached and overcome by German and Japanese firms. The Japanese firm are the ones with the largest increase and the largest cumulative value at the end of the period under analysis.

The Dutch firms have been included as a reference, they are ranked fourth in this particular classification, but the gap with the first three countries under analysis is tremendous. In fact, the total FIR patents for the Dutch firms at the end of the period are a little more than one tenth of the patents showed in the American firms' case. It remains clear that the most advanced countries are Japan, Germany and the US, confirming also in the case of the FIR what has been documented in the literature on innovation[28].

Once determined the geographical origin of the firms that recorded most patents in the EPO, a breakdown of the most innovative companies is presented in Figure 2.11. The most

[28] For further evidence see also: Thelen (2004); Nelson (2013) for a bigger picture on the innovation topic on Japan, Germany and US, and Taglioni and Winkler (2016), Buonafede et al. (2018) for a specific description on the new technologies.

innovative firms are the German Siemens and the Japanese Sony, confirming also what shown in the graph gathering all the firms by home country.

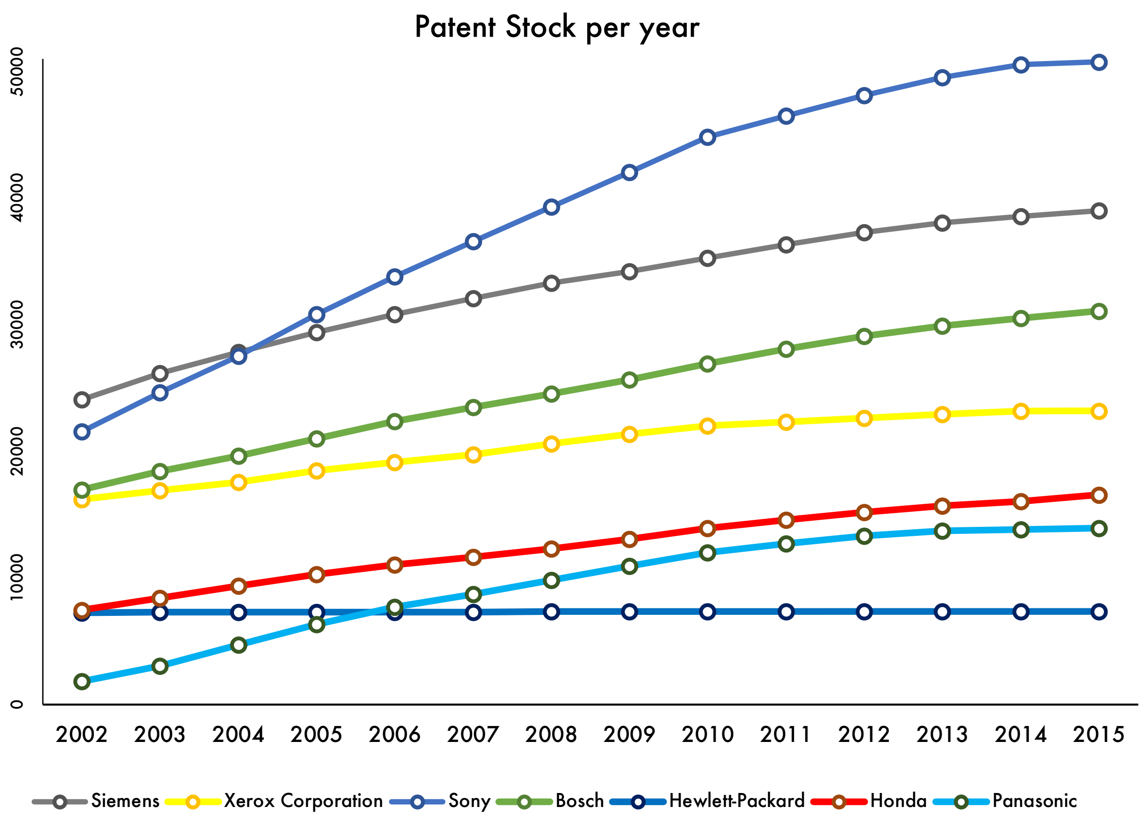

Figure 2.11 - Number of patents for the first applicant firms. Source: GPI. Own elaboration.

The graph shows that the Japanese firms, including hence Sony, Honda and Panasonic, present almost constant growth rate for the stock of the patents. On the other hand, the German Siemens and Bosch, have similar patterns for the growth, but flatter than the Japanese ones. The American Xerox Corporation shows a slow growth rate, while Hewlett-Packard features the flattest increase, with the total number of patent application growing only by a few units in each of the years in the sample. It is interesting to note that all the first seven firms, at the beginning of the period under analysis, are reported in the same rank as at the end. The two changes of position are the one by Sony on Siemens in 2004 and the one by Panasonic on Hewlett-Packard in 2006. Once the statistical values are computed, the cumulative number of patents at country level can be a proxy of the attractiveness of the country for an eventual RSD, while the number of patents for the firm can be used in describing the propensity for a firm to undertake a relocation.

Chapter 3: Analytical Research

3.1 Model Setting

The model used for the econometric analysis is a logit regression model using the software STATA. This typology of model is used when employing a binary dependent variable. The logistic regression is based on a statistical linear function. The function that is used to put in relationship the dependent variable with the independent variable, namely the link function, is called logit function. It is defined on the interval (0, 1), with variables representing a probability of occurrence of a certain event. The function is defined as:

$$logit(p) = ln(p) - ln(1-p) = ln\,(\frac{p}{1-p})$$

Where *ln* is the natural logarithm and $\frac{p}{1-p}$ is called odd, namely the ratio between the probability of occurrence of an event and the probability of non-occurrence of the same event. Below the plot of the logit variable is shown (Figure 3.1).

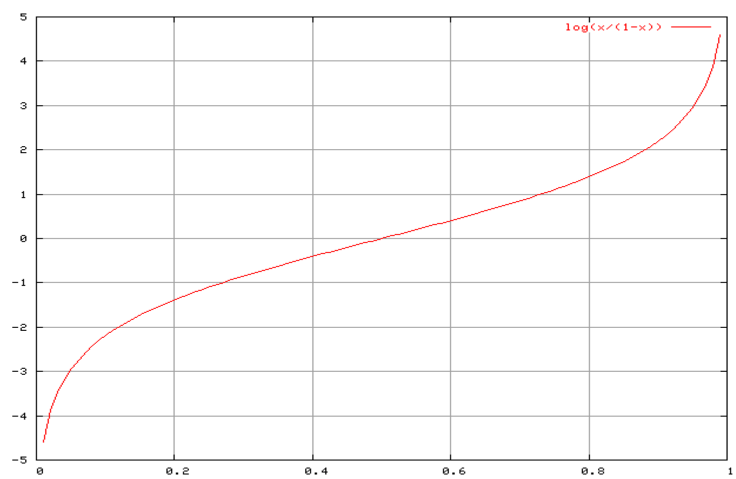

Figure 3.1 - Plot of the logit function

Following the definition of the link function, the model is described by the equation:

$$P(y=1|\boldsymbol{X}) = \beta_0 + \beta_1 x_1 + \cdots + \beta_k x_k = \boldsymbol{X}$$

Where P(y=1|X) is probability of a positive outcome for the dependent variable conditional to the occurrence of the conditions described by the explanatory variables, the vector X' represent the explanatory variables (observed characteristics), and the coefficients β_i terms are the estimated impact that the regressors have on the probability of a positive outcome.

3.2 Definition of the variables

3.2.1 Dependent variable

The dependent variable of the model is a binary variable modelling the RSD decision. Specifically, the variable is called *RHC* and assumes the value 1 if the firm conducts an RHC. On the contrary, the variable is set to 0 if the relocation operated is an RTC. The total number of relocations in the dataset is 535; however, due to data availability issues on the RHS, the number of observations drops to a lower number depending on the specified model. The definition of the control variables will be discussed in Section 0.

3.2.2 Explanatory variables

In the logit regression model, four explanatory variables are used in determining the location advantages for an RSD. These advantages are the same described by Dunning (1993)[29].

Patents in FIR technologies

A variable representing the grade of innovation of the firm is modelled. The application of patents in matter of the FIR is used as a reference for the level of innovation of the company. Given the data gathered on the Global Patent Index (GPI)[30] database provided by the European Patent Index, the variable accounts for the number of patents in the sphere of the FIR. In particular, the variable represents the stock of the applied patents in Industry 4.0 for the firm operating an RSD. The reference year is the announcement year of the relocation. Given the discussion in the literature review section, a positive correlation between the level of innovation and the willingness to relocate in the home country the productive activities is expected. Thus, a correlation between the variable regarding the patents and the dependent variable is expected.

Industry 4.0

Whether the presence of an Industry 4.0 initiative can be a driver for the relocation to the home country is a matter that has been already discussed in the literature review section.

[29] Given that some variables express numbers with different units of measure and various orders of sizes, standardization is used to obtain more homogeneous values of variables on the RHS.
[30] See: Section 2.2.2 for the description of the data; Annex 2 for the description of the method of the extraction of the data.

Thus, a dummy variable has been created to prove the differential presence of an eventual initiative. In particular, if a firm heads, with a RSD, towards a country where an Industry 4.0 program is in force leaving a country where there is not such an initiative, the variable is set to 1. In the other cases, the variable is set to 0. The way in which the variable is built, allows to check the difference between a neutral country and a country actually investing in the development of Industry 4.0. This, in my intention would give a proxy of the attractiveness of the country, in this dimension of analysis

Market-seeking

This explanatory variable captures the role of the of the *market-seeking* factors (Barbieri et al. 2018), and is measured as the difference in the nominal GDP, computed at Purchasing Power Parity. The variable considers, when called *Offshoring Market Driver*, the difference between first host and home country and, when called *Relocation Market Driver*, between second and first host country. In this case, when the RSD is a RHC, it is important to recall that the second host country corresponds to the home country. The variable is built as the difference of the averages of the punctual values in the three years preceding the announcement year of the RSD. This measure is expressed in constant 2011 US dollars and is retrieved from the World Development Indicators database of the World Bank. The use of such variable is aimed at defining to what extent a country may result more attractive than another one in terms of market opportunity, since the level of the GDP a specific country is considered a proxy of the possibility to expand the market in the country under analysis. The variable is standardized according the procedure described in Section 3.2.2.

Strategic-asset seeking

The variables used as drivers for the *strategic asset-seeking* factors are the differences in the number of researchers in the R&D division per millions of people (Source: World Bank). Also, in this case, the variables are the difference of the average in the three years' values prior to the announcement's year of the relocation. As for the market-seeking variable, the differential values are calculating for the first host and home country, for the first regression and it is called *Offshoring Asset Driver*. For the second model, instead, the difference is between the second and the first host country, and it is called *Relocation Asset Driver*. Also, in this latter case, it is important to recall that, if the RSD is a RHC, the second host country corresponds with the home country of the firm.

Efficiency-seeking

The *efficiency-seeking* factor is based, in turn, on two sub-factors, namely the *cost-seeking* and the *productivity-seeking* advantage. These variables are called *Offshoring Cost Driver* and *Offshoring Productivity Driver* when they are computed as the difference in the value between the first host and home country. On the contrary, they are called *Relocation Cost Driver* and *Relocation Productivity Driver*, when they are computed for second host and first host country. The cost-seeking is expressed by the unitary labour cost. As for the others location drivers, if the RSD is a RHC, the second host country coincide with the home country. This information is extracted from the OECD Compendium of Productivity Indicators, measured in the base year 2010=100. As far as concerns productivity variable, it is expressed by the value of GDP per person employed, expressed in constant 2011 US millions of dollars, at the purchasing power parity. This information is retrieved from the World Development Indicators database of the World Bank. As for all the other location advantages, the values of both efficiency-seeking indicators are represented by the difference of the average of the values in the three years preceding the announcement year of the relocation.

3.2.3 Control Variables

In addition to the variables representing the factors driving a relocation, other variables are introduced as controls, as they may affect the choice for a RSD. The variables take into consideration data regarding the company, the country of origin and destination or the period in which the RSD took place.

Size of total Assets

Total assets are used to measure the *Size* of the company. Furthermore, most of the firms in the sample belong to different industries in terms of labour and capital-intensity, so the size of total assets is evaluated as a good proxy of the dimension of the firm (Barbieri et al. 2018). The data are retrieved by the Orbis – Bureau van Dijk database, as an average of the total assets for the timespan of the investigation (2002-2015). The value is expressed in thousands of US dollars.

High-tech control

The *high-tech* dummy variable has value 1 for the companies that operates in industries characterized by a medium-to-high level of technology, and 0 for the others, namely the ones with a lower content of technology. The source is the Eurostat-OECD classification (2007). Some examples of companies belonging to the medium-high tech segment are the producers of electronic appliances like Philips or Samsung and the car producers Renault and Ford; on the other hand, among the companies characterized by a lower level of technological content, there are the food producers like Kraft Foods, Nestlé and Mars and the tyre manufacturers, like Goodyear and Michelin.

Crisis period

Two control variables are introduced, to examine the effects of the of the economic crisis of 2007-2008. *Crisis 08-11* is the dummy that distinguishes the relocations announced during the years of the crisis. The global recession lasted from the year 2008 to 2011, for this reason, the variable assumes value 1 if the announcement year of the relocation is in the timespan defined, and 0 otherwise.

A second dummy, called *Crisis 12-15*, is used to give relevance to the post-crisis years. In this case the variable assumes value 1 if the observation has an announcement year included in the interval going from 2012 to the end of the research time horizon, and 0 otherwise.

Eastern host country

Looking at the destinations of the relocations, two dummies are introduced in order to distinguish a particular subset of countries. In particular, *Host1, East-EU* controls if the first host country and *Host2, East-EU,* the second host country[31] is a country belonging to the Eastern Europe. The countries that refer to the Eastern Europe are those ones entered in the European Union in the expansion of 2004 and 2007, plus some others, not belonging to the EU. The countries are Slovenia, Hungary, Romania, Slovak Republic, Poland, Czech Republic, Latvia, Estonia, Lithuania, Bulgaria, Croatia and Serbia. The variables assume value 1 if the country belongs to the list above and 0 otherwise.

Once all the variables are defined and conceptualized, the empirical analysis consist in estimating the effect for the dependent variable of all the explanatory variables, in relationship with the control variables.

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[31] As for the explanatory variables, it necessary to specify that the second host country, in the cases of RHC is the home country of the firm.

3.3 Empirical Findings

3.3.1 Differential between first host and home country

The analysis covers the period from 2002 to 2015, recording 535 relocation instances, carried out by 318 firms, into a space formed by 52 countries. Two models are displayed, namely one including the Industry 4.0 variable and one including the Patents in FIR technologies variable. A third model, instead, considers the two variables together. This analysis is related to the differences between the first host and home country, for what concerns the level of the variables considered. The complete representation of the numerical results is displayed in Annex 4.

As the Table 3.1 shows, the choice of the RHC has a positive significant relationship with the market-seeking driver. The positive correlation, although weak in one case, of the size suggests that larger firms are more likely to undertake RHC.

On the other hand, the variable reflecting cost-seeking offshoring has a negative and significant relationship with the choice of an RHC. Consistently, the presence in the Eastern Europe as second host country is in strong negative correlation with the dependent variable suggesting a propensity for a company deciding for a RTC to opt for an eastern European country. Hence, the Eastern Europe countries can be defined as one of the main destinations for an RTC. A correlation emerges, instead, with the size of the total assets, in positive connection with the RHC variable[32]. The asset differential, differently, is weakly correlated with a positive coefficient with the RHC only in the specification controlling the patents. Given this result, it is possible to affirm that there is an attraction effect by the R&D effort by the home countries. It is possible to notice, furthermore, a relationship with the crisis period, in particular, the correlation is stronger with the first period of the crisis. Since the correlation is positive, this result may be interpreted as a confirmation of the relationship between the crisis period and the RHC. Table 3.1 also reports the results of the logit regression for the subset of firms having a headquarter in the European Union[33]. The main difference is the

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[32] For a detailed description of the results, see Barbieri et al. (2018)

[33] A subset of observation has been created according to the origin of the firms. In particular, the firms having the headquarter in the European Union are including in this subset. In this way, it is possible to study what the drivers for the decisions of the European firms are.

absence of significance of the market-seeking driver. The other drivers follow the same pattern as in the whole sample.

	Industry 4.0 Only		Patents Only	
	Sample	HQ in EU	Sample	HQ in EU
Offshoring Market Driver	1.857*** (-5.57)	-0.032 (-0.03)	1.838*** (-5.74)	-0.167 (-0.17)
Offshoring Asset Driver	0.33 (-1.37)	0.276 (-1.06)	0.378* (-1.73)	0.328 (-1.43)
Offshoring Cost Driver	-0.482* (-1.72)	-0.501 (-1.56)	-0.536** (-1.96)	-0.536* (-1.77)
Offshoring Productivity Driver	-0.006 (-0.02)	-0.126 (-0.54)	-0.16 (-0.46)	-0.28 (-0.97)
Crisis 08-11	0.888* (-1.74)	1.181** (-2.19)	1.113** (-2.16)	1.367** (-2.5)
Crisis 12-15	0.943* (-1.69)	1.048* (-1.67)	1.025* (-1.76)	1.234* (-1.88)
Size Total Assets	0.271** (-1.99)	0.214 (-1.48)	0.216* (-1.77)	0.145 (-1.12)
Host1, East-EU	0.955 (-1.28)	0.011 (-0.01)	0.74 (-0.96)	-0.154 (-0.18)
Host2/Home, East-EU	-3.858*** (-5.20)	-3.669*** (-5.40)	-3.669*** (-4.54)	-3.540*** (-4.74)
Euro-Currency	-0.453 (-0.87)	-0.581 (-0.90)	-0.494 (-0.97)	-0.613 (-0.99)
High-Tech Control	0.657 (-1.39)	0.57 (-1.08)	0.831* (-1.89)	0.765 (-1.54)
Industry 4.0	0.002 (-0.01)	-0.021 (-0.12)		
Patents in FIR technologies			0.253 (-0.32)	-0.196 (-0.25)
N of obs.	262	174	290	202
Wald Chi2	79.365***	59.158***	74.552***	60.51***
Pseudo R2	0.4324	0.3661	0.4291	0.3796

Table 3.1 - Results of the Logit econometric model Home vs Host1.
Z-Statistic in brackets. [p<0.10, **p<0.05, ***p<0.01]*

Table 3.2 displays the results for the model including both the Industry 4.0 and the Patents. The pattern is similar to the two models considering the variables separately. In fact, the market seeking driver for the host country is positively correlated as well as the size of the total assets and the crisis control. On the other hand, the cost reduction driver and the control of the second host country in the Eastern Europe are negatively correlated. In this case, also, there is no significant correlation with the asset seeking drivers.

The main difference is in the loss of importance for the control on the post-crisis period (2012-2015). This is true for the whole sample and also for the subsample of firms having the headquarters in the European union.

As for the models including the variables individually, the regression does not highlight any correlation with the two core variables of the analysis. Those variables, in fact, do not show any correlation with the dependent variable. For this reason, the analysis has been extended to a further dimension.

In particular, the variables considering Industry 4.0 and the number of patents, have been analyzed by studying the interaction factor with the three of the four factors of the framework for the motivation of the location advantages expressed by Dunning (1993). In particular, the three variables considered are the two components of the efficiency seeking factor, namely the productivity enhancing and cost reduction variables, and the asset seeking variable. A study of the interaction between the market seeking factor and Industry 4.0 and number of patents would have been less meaningful, given that the latter are less likely to be in relationship with the expansion of the potential market.

	Industry 4.0 and Patents	
	Sample	HQ in EU
Offshoring Market Driver	1.857*** (-5.58)	-0.09 (-0.08)
Offshoring Asset Driver	0.33 (-1.37)	0.272 (-1.05)
Offshoring Cost Driver	-0.482* (-1.72)	-0.502 (-1.54)
Offshoring Productivity Driver	-0.004 (-0.02)	-0.12 (-0.53)
Crisis 08-11	0.893* (-1.74)	1.229** (-2.22)
Crisis 12-15	0.956 (-1.54)	1.164 (-1.64)
Size Total Assets	0.270** (-1.99)	0.207 (-1.44)
Host1, East-EU	0.957 (-1.28)	-0.006 (-0.01)
Host2/Home, East-EU	-3.867*** (-5.05)	-3.735*** (-5.26)
Euro-Currency	-0.45 (-0.85)	-0.552 (-0.85)
High-Tech Control	0.659 (-1.39)	0.579 (-1.08)
Industry 4.0	0.004 (-0.02)	-0.009 (-0.06)
Patents in FIR technologies	-0.062 (-0.07)	-0.497 (-0.59)
N of obs.	261	174
Wald Chi2	80.158***	58.69***
Pseudo R2	0.4313	0.3673

Table 3.2 - Results of the Logit econometric model Home vs Host1.
Z-Statistic in brackets. [p<0.10, **p<0.05, ***p<0.01]*

From the analysis[34], a negative and significant interaction emerges for the cost seeking variable and Industry 4.0, in the test considering the entire sample. This implies that the presence of an Industry 4.0 policy in the second host country would intensify the effect of the cost reduction driver. In other words, Industry 4.0 policy in the third country amplifies the probability that cost-saving firms relocate to a third country.

Concerning the number of patents, an important result emerges. This variable, in fact, is positively correlated with the dependent variable if interacted with the asset-seeking driver. This means that the attractive power of the R&D effort by the home country is enhanced if the firms has a high level of technological content.

A peculiar situation emerges for the EU subsample of firms. In fact, the two technological variables, i.e. Industry 4.0 and the patents, have a significant coefficient if interacted with the cost drivers and the asset-seeking. However, the two drivers, by themselves, do not have a significant correlation with the dependent variable. The peculiarity of this result is represented by the fact that the significance of the driver appears only in the case in which it is linked with the variable. In particular, the cost advantage is significantly and negatively correlated only if linked with the variable Industry 4.0, as for the case covering the whole sample. On the other hand, the patents have a different influence, in fact, the interaction coefficient is positive. So, it is possible to affirm that a high number of patents mitigates the negative influence of the cost reduction in opting for a RTC. This may diminish the probability for a firm adopting a high level of new technologies, in presence of cost advantages, to opt for a RTC.

So, at the end of the first analysis, it is possible to affirm that for particular subset of variables, the adoption of patents regarding the new technologies and Industry 4.0 have an influence.

[34] See Annex 3 for the complete report of the numerical results in the interaction analysis.

3.3.2 Differentials between second host/home and first host country

After having conducted an analysis regarding the home country and the host country, the point of observation is shifted. I now present the results of the second regression analysis conducted, this time considering the first host country and the second host country. In other words, the test focuses on the country of origin and the destination of a RSD. It is important to recall, that all the results of this model consider the second host country, when the RSD is a RTC, while the first host country is considered, in case of RHC. The complete representation of the numerical results is displayed in Annex 4.

With this approach, all the variables describing a differential between two countries do not regard anymore the difference between the first host and home country, but, the two host countries. As for the first specification, the models are three. The first one includes only the variable of the Industry 4.0 initiatives; the second refers only to the effect of the patent for the new technologies; the third, finally, considers both the drivers for the FIR's initiatives and the stock of the patents for the firm (Table 3.4). As for the case in which are considered the home country and the first host country, also in this regression there is a further analysis on the subset of countries with the headquarter in the European Union.

Going in detail with the analysis, it is possible to notice that the market- and asset-seeking drivers have a positive and significant correlation with the dependent variable. Limited to the asset-seeking driver, the correlation does not hold for the firms having the headquarter located in the EU. On the other hand, the correlation for the market-seeking driver does not hold for the model considering the only patents (Table 3.3). As for the specification in Section 3.3.1, the cost-reduction driver has a negative and significant correlation. But, in this case, this happens only for the subset of firms having the headquarter in the EU.

A measure expressing correlation with the dependent variable is the control for the period of the crisis 2007-2008. This is valid only for the European firms, confirming part of the results for the regression of the previous section. The crisis, in fact, contributed to RHC for many European firms. The period after the crisis, instead, showed a lower correlation with the RHC. In fact, only in the regressions considering individually Industry 4.0 and the patents, and only for the European firms, the RHC are also influenced by this period, being the correlation significant and positive. In particular, this happens in the two models considering the patents.

	Industry 4.0 Only		Patents Only	
	Sample	HQ in EU	Sample	HQ in EU
Relocation Market Driver	0.333 (-1.61)	0.359 (-1.53)	0.358* (-1.83)	0.478** (-2.08)
Relocation Asset Driver	0.460** (-2.22)	0.23 (-1.05)	0.495** (-2.53)	0.31 (-1.5)
Relocation Cost Driver	-0.2 (-0.93)	-0.414* (-1.73)	-0.249 (-1.24)	-0.478** (-2.03)
Relocation Productivity Driver	0.137 (-0.61)	0.292 (-0.98)	0.216 (-0.93)	0.468 (-1.2)
Crisis 08-11	0.481 (-1.16)	1.061** (-2.01)	0.635 (-1.57)	1.237** (-2.35)
Crisis 12-15	0.427 (-0.91)	0.816 (-1.53)	0.472 (-1)	1.061* (-1.87)
Size Total Assets	0.01 (-0.07)	0.19 (-1.28)	-0.061 (-0.43)	0.076 (-0.6)
Host1, East-EU	-0.586 (-0.85)	-1.124 (-1.17)	-0.806 (-1.20)	-1.525 (-1.58)
Host2/Home, East-EU	-2.680*** (-3.41)	-2.984*** (-3.15)	-2.564*** (-3.51)	-2.769*** (-2.96)
Euro-Currency	-0.522 (-1.12)	-0.779 (-1.16)	-0.634 (-1.39)	-0.824 (-1.26)
High-Tech Control	0.017 (-0.04)	0.34 (-0.69)	0.13 (-0.36)	0.505 (-1.12)
Industry 4.0	-0.078 (-0.44)	-0.061 (-0.36)		
Patents in FIR technologies			-0.249 (-0.36)	-0.719 (-0.92)
N of obs.	257	172	286	200
Wald Chi2	57.541***	51.554***	61.661***	53.803***
Pseudo R-Squared	0.3107	0.3589	0.3155	0.3786

Table 3.3 - Results of the Logit econometric model Host1 vs Host2/Home. Z-Statistic in brackets. [p<0.10, **p<0.05, ***p<0.01]*

From the second specification, as well as the first one, it emerges that the size and the sector of the company does not have any correlation with the choice of a RTC or RHC. This effect is also confirmed for the first host country in the Eastern Europe and the use of the Euro currency. On the contrary, there is a strong effect for the destination in Eastern Europe. Since the coefficient is negative, it suggests that many RTC are directed towards the countries of Eastern Europe, confirming once more the trends highlighted in the sections of descriptive statistics and also in the previous specification.

In order to have a deeper analysis, the interaction between the location advantage drivers and the variables of Industry 4.0 and the number of patents has been examined. Once computed the interaction between Industry 4.0 and the asset seeking advantage, a significant negative coefficient arises. On the contrary, the asset seeking differential, taken individually has a positive coefficient. For this reason, it is possible to affirm that the presence of an Industry 4.0 initiative decreases the attractiveness of the home country for asset-seeking firms. So, for a firm pursuing asset advantages, the most probable decision would be a RHC, but if in the home country an Industry 4.0 policy is in force, the probability for this decision will decrease.

As for the first specification, a peculiar result emerges in the analysis of the European subsample. The cost advantages have an influence only if interacted with the number of total patents. The coefficient of the interaction is positive, and so this may moderate the influence of the cost advantage in relation to the RTC.

The same happens for the variable of Industry 4.0. In fact, also in this case, the correlation emerges only if the driver is linked with this variable. In this case, it is possible to affirm that, if a firm is initially oriented towards a RTC for cost reduction reasons, the probability for the RTC will increase if in the second host country an Industry 4.0 policy is in force.

	Industry 4.0 and Patents	
	Sample	HQ in EU
Relocation Market Driver	0.344* (-1.66)	0.398* (-1.66)
Relocation Asset Driver	0.468** (-2.27)	0.26 (-1.17)
Relocation Cost Driver	-0.201 (0.94)	-0.424* (-1.75)
Relocation Productivity Driver	0.132 (-0.59)	0.284 (-1.02)
Crisis 08-11	0.511 (-1.22)	1.135** (-2.13)
Crisis 12-15	0.508 (-1.01)	1.022* (-1.68)
Size Total Assets	0.004 (-0.03)	0.176 (-1.19)
Host1, East-EU	-0.598 (0.87)	-1.182 (-1.23)
Host2/Home, East-EU	-2.699*** (-3.44)	-3.039*** (-3.20)
Euro-Currency	-0.498 (-1.05)	-0.739 (-1.08)
High-Tech Control	0.012 (-0.03)	0.354 (-0.7)
Industry 4.0	-0.062 (-0.33)	-0.034 (-0.21)
Patents in FIR technologies	-0.384 (-0.51)	-0.842 (-0.98)
N of obs.	257	172
Wald Chi2	*57.566****	49.495***
Pseudo R-Squared	0.3115	0.3623

Table 3.4 -Results of the second model. Host1/Host2 (dependent variable: RHC)
Z-Statistic in brackets. [p<0.10, **p<0.05, ***p<0.01]*

Chapter 4: Discussion of the results

This research provides some important insights on the RSD. The econometric results, in some cases confirm the general trends highlighted in the descriptive statistic sections. In other cases, the regression does not prove the correlation between the dependent variable and the two measures of the new technology adoption.

For both of the tests executed, there is no correlation between the dependent variable and the variables controlling the influence of the new technologies. This result may imply to give a negative answer to the research question. Nevertheless, some other conclusions can be drawn, considering the test using the interactions between the two variables and the drivers for the location advantage.

4.1 Analysis of the first Specification (First host country vs Home country)

Starting from the first regression analysis (Section 3.3.1) the results partially confirm the theoretical findings of Barbieri et al. (2018). The RHC, in fact, is a choice for the firms pursuing an expansion of the potential market. The market-seeking variable, in fact has a strong positive correlation with the dependent variable. Furthermore, for the firms choosing an RHC, there is a confirmation of some behaviours already discussed in the theory. As a matter of fact, the RHC practice is chosen by the larger firms, since the variables controlling the size of the total assets are in a significant and positive relation with the dependent variable. So, it is reasonable to affirm that the RHC is a strategy adopted by larger firms in a perspective of concentration of the demand. This kind of behaviour is suggested in the literature as one of the basic determinants for back-reshoring (Kinkel 2012). When the subject of analysis is the subsample of firms that have the headquarters in the EU, the situation is different. In fact, for this subsample, the market-seeking driver is not correlated with the dependent variable.

Another confirmation of the results of Barbieri et al. (2018), comes from the cost reduction dimensions of the efficiency-seeking factor, whose values express negative correlation with the RSD variable. In this case, the firms pursuing efficiency, by a reduction of the costs, adopt a policy of RTC. The pursuit for productivity is a driver defined as a triggering factor for a RSD, recalling the interpretative framework proposed by Fratocchi et al. (2015). So, also this result is consistent with the extant literature.

For what concerns the cost reduction driver, the correlation, although significative, is weaker for the European firms than in the entire sample. This outcome suggests that, for the firms hailing from the EU, the cost reduction driver has a lower relative importance with respect to the entire sample, in choosing between a RTC or a RHC.

For what concerns the cost reduction driver, the correlation is weaker for the European firms than for the entire sample. This outcome suggests that, for the firms hailing from the EU, the cost reduction driver has a lower relative importance with respect to the entire sample, in choosing between a RTC or a RHC.

The productivity-enhancing driver, on the contrary, does not have any significant correlation in none of the models of this specification, suggesting that the productivity enhancing is not a relevant factor in the decision between a RHC and a RTC. The same outcome is verified for the asset-seeking driver. Also, in this case, there is no correlation, exception made for only one test, in which, in addition, the variable has a weak correlation with the dependent variable. Given the outcomes for the drivers of asset seeking and productivity, it is possible to consider their effect on the dependent variable as negligible.

A variable considered to be in relationship with RSDs is the control of for the second host country (or the home country in case of RHC) in the eastern European union. In fact, this control is in a strong, negative correlation with the dependent variable. This implies that, when deciding a destination for a RTC, the most preferred destinations are the eastern European countries. This is also proved by the data in the descriptive statistics section. In fact, Section 2.1 shows that Poland, Czech Republic and Romania are among the most chosen destinations for a relocation, and in particular, those countries are destinations for RTC only.

The correlation is irrelevant for the variable controlling the use of Euro currency in the first host country and the category of the firm. Hence, Euro currency or the high-tech output, do not seem to represent a distinctive factor in terms of choice between a RTC or RSD. This outcome is valid in either the two dimensions of analysis: the one considering all the firms in the sample and also the one with the firms headquartered in the EU. The result concerning the high-tech products is in line with the findings of Barbieri et al. (2018), according to which the distinction in terms of output has no relevance if the choice is between a RHC or a RTC.

A peculiar case is represented by the control of the crisis, and in particular, the one determining if the RSD took place in the years of global recession (2008-2011). For this control, in fact, there is a weak correlation only for the firms having the headquarters in the EU. This outcome was also discussed by Kinkel (2012). The author, in fact, observed an overall decline of the total relocation, while the number of RHC kept constant. For this reason, the incidence of the RHC over the total RSD grew in importance. Furthermore, considering that the data source of the work by Kinkel (2012), is the EMS, the outcome of an "European-only" trend finds further confirmation. On the other hand, the result, for the post-crisis period (2012-2015) exhibits a weaker effect, so it is possible to affirm that the RHC are less influenced by the post-crisis period, with respect to the crisis period.

Finally, the variables representing the core of the analysis seems to be providing a disappointing result. In fact, the number of patents of the relocating company and the influence of Industry 4.0, do not have any direct correlation with the dependent variable. The p-value obtained by the regression[35], indeed, result much above 0.1. For this reason, the variable cannot be used as an explicative factor influencing the choice of a RTC or RHC.

As explained in Section 3.3.1, the research has been deepened by studying the interactions of the two variables with the location advantages. Given the different sign of the results, two different insights arise. The first one is the positive correlation expressed by the interaction of the patents and the asset seeking advantage. In this case, it is possible to infer that a firm with a higher level of new technologies, will have an higher probability to proceed in an RHC. So, a linkage between the asset seeking advantages and the patents can be highlighted: in particular, a firm choosing a strategy oriented to the asset seeking, will have a higher propensity towards a RHC, if it has already adopted a large number of new technologies.

As regards the cost-saving variable, the significant interaction with the Industry 4.0 variable is negative, thus suggesting that this variable enhances the probability to opt for a RTC for a firm pursuing cost advantages. In fact, the cost advantages, by themselves already drive the firms into a RTC choice; in this case, the presence of an Industry 4.0 policy in a third country, can be a further incentive for a relocation towards a that particular county.

[35] See Annex 3 and Annex 4 for all the numerical outcomes of the regression analysis.

4.2 Analysis of the second Specification (second/home vs first host country)

The second regression is built by using the differential variables between the second host (or the home country, in case of RHC) and the first host country. In doing so, a measure of the level of attractiveness of the third country can be given, in relationship with the dependent variable, distinguishing between RTC and RHC.

The first variable analysed is the market-seeking factor. This variable has a weak correlation with the dependent variable for the model considering both the new variables (Industry 4.0 and the patents) and the patents only. In the model considering only the Industry 4.0 variable, instead, no correlation emerges. As it happens in the regression considering home country, the coefficient of the variable in the regression is positive. Hence, it suggests that the firms pursuing a market-seeking strategy will choose a RHC. This figure is in line with the previous experiment and also with the theoretical hypotheses of Fratocchi et al. (2015). Also, in this case there is a propensity for a RHC for the firms trying to expand their market for their demand.

A distinctive point of the result of the second typology of regression is the emergence of the relevance for the asset-seeking factor. In fact, the variable becomes significantly correlated with the dependent one. The results, displayed in Section 3.3.2, show a positive and significant coefficient, limited only to the entire sample, for the asset-seeking driver. In this case, the possibility for a RHC are positively influenced by higher level of R&D effort. Again, the home country characteristics are one of the five determinants presented by Fratocchi et al. (2015). So, the relevance of the asset-seeking driver theorized in the literature, finds further support in the econometric model.

Shifting the focus on the efficiency-seeking factor, there is correlation for the cost-reduction, while, for the productivity-enhancing driver, none of the models shows any linkage with the dependent variable. In particular, the cost reduction driver is correlated with the RHC variable, only for the model considering the firms with the headquarters in the EU. For this factor, the regression coefficient is negative, thus, confirming the attitude of the firms pursuing a cost reduction strategy to move towards a third country. Differently from the first specification, however, this attitude can be only referred to the European-born firms.

The European origin of the firms has an effect also in the definition of the role of the economic crisis. In fact, the coefficients are positive and significant for the subset of firms originating in the EU. This result is not only in line with the first experiment, but also expresses the general effect of the crisis on the European firms, confirming the intuitions of Kinkel (2012). For two models, out of the six in the second specification, a correlation can be retrieved also for the years following the period of recession. In fact, the control of the post-crisis period (2012-2015) resulted to be in a negative correlation, although weak, with the dependent variable. In particular, such a correlation is valid for the subset of the European firms. This may represent a mathematical confirmation for the intuition of the stream of RHC started because of the global recession of 2008. Hence, it is possible to affirm that the crisis had a positive influence on the firms and their choices to relocate, towards their home country.

As for the specification involving the first host country and the home country, the controls regarding the use of the Euro currency and the distinction in terms of output have no significance. For both variables, in fact no correlation of any type can be retrieved with the dependent variable. Furthermore, differently from the other regression test, no distinction can be made among the entire sample and the one including only European firms.

Distinguishing the two variables controlling the first host and the second host countries, the effects are different. The location in the Eastern Europe of the first host country (*Host1, East-EU*) has no significant correlation with the dependent variable. So, it is possible to affirm that the country of origin of the RSD, is irrelevant for the choice between of the RHC or a RTC. On the contrary, the Eastern Europe control of the second host countries (*Host2/Home, East-EU*) has a very strong correlation with the dependent variable. In particular, since the correlation is negative, it is possible to infer that, in general, that firms are oriented towards Eastern Europe when opting for a RTC. This fact is not surprising at all and it was clear already from the descriptive statistic section (2.1). Eastern European countries are, indeed, the most frequent destination for the RSD, specifically of the RTC type.

The size of the total asset does not have any relevance for the RSD. The dependent variable, in fact, proved not to be in any correlation with the control regarding the size of the firm.

The regression tests have been explicitly modelled in order to include the variable checking the presence of and Industry 4.0 initiative and the level of innovation of the company. Despite the purpose, the two variables modelling the two phenomena have no statistical relevance in explaining the dependent variable.

The outcome of all the regression (including the entire sample and the European subsample) provided a disappointing result. As a matter of fact, none of the variables have any correlation with the dependent variable.

Given these results for the Industry 4.0 and the patents, I conducted an analysis on the interactions[36] between the location advantages drivers and these two variables.

A first result provided by this test, is that Industry 4.0 has an effect if connected with the asset seeking driver. In fact, from the statistical analysis it emerges that, if in the second host country the firm may find an high R&D effort and in that country an Industry 4.0 policy is in force, it will reduce the probability of the firm to opt for a RHC. This result arises from the negative and significant, although weakly, regression coefficient of the interaction.

Furthermore, there are two results that worth a mention. As regards the first one, there is a significant and positive correlation of the variable accounting for the number of patents and the cost reduction driver. The interpretation of this result is that the degree of innovation determines a decline in the propensity for the RTC for the firms pursuing cost advantages. This outcome is given by the discordance between the driver and the respective interaction. Such a difference in the mathematical sign of the two items, in fact, reduces the probability of the decision originally traced by the driver itself. The cost variable shows a similar behaviour also if interacted with the Industry 4.0 control. In this case, the coefficient results negative, and significant, while the costs seeking variable, individually does not have a significant correlation. This may suggest a higher propensity for the firms pursuing cost advantages to choose a RTC, if in the second host country an Industry 4.0 policy is in force. It is necessary to specify that these two last outcomes are valid only for the European firms and cannot be extended to the entire subsample.

At the end, the results provided by the interaction test are useful to show, that, although a clear and distinctive pattern of attractiveness for Industry 4.0 and the patents adoption cannot be detected, a continuation of the research in this direction may bring some interesting results.

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[36] See Annex 3 for the complete display of the results of the interaction tests.

4.3 Remarks on the results and suggestion for further research

At the end of the analysis, it is possible to give an answer to the research question formulated in Section 1.3. The national initiatives of Industry 4.0 and the FIR patents do not have an explicit influence on the RHC. However, looking at the interaction tests, we can claim that they have a moderating effect. So, the hypotheses of the previous section cannot be entirely rejected.

In particular, the analyses using the cost differentials give some interesting result. For instance, the decision on the basis of the cost advantage becomes significant for the firms with an high technological level and drives them to a RHC. On the contrary, an Industry 4.0 initiative in the second host country, is an attractive factor for the firms pursuing cost advantages. This effect is also verified for the cost differentials between second host (or home) and first host country. In general, it turns out that the cost advantages, jointly with an Industry 4.0 policy can be considered as a stimulus for a RTC.

The attractive capability Industry 4.0 in terms of an RTC can be detected also in case of the asset seeking policy by the firm. On the contrary, looking at the patents, an asset seeking behavior can be considered as a stimulating factor for the RHC. At the end it is possible to affirm that, limited to the asset seeking and cost reduction behaviors, the firms will choose a RTC if an Industry 4.0 policy is in force in the country of final destination. Conversely, if the company has a high level of implementation of the patents, the preferred choice will be a RHC.

Furthermore, if the location drivers are generally related to particular type of decision, namely the cost reduction with the RTC and the asset seeking to the RHC, the presence of the technological variables mitigate the effect of these two drivers. In particular, the RTC probability declines if the cost reduction advantage is in relationship with the patents. Conversely, the probability for RHC diminish if the asset seeking advantage is linked to Industry 4.0.

In addition to this, the analysis of the descriptive statistics gives a general idea that the countries have already implemented some Industry 4.0 plans are attractive destinations, both of the RHC and RTC types. In particular, Germany, Italy, France and the United Kingdom rank among the first countries of destination of the RTC (see Section 2.2). At this point, in order to obtain more relevant results about the attractiveness of the countries implementing the programs, an introduction of a control sample of firms, (i.e. the counterfactual analysis) could be useful to distinguish if the national initiatives are really an attractor for the relocations. In this perspective the role of Poland, may change. In fact, Poland has a plan for Industry 4.0 since 2016, but it is already the most frequent destination for a RTC. A thorough analysis of Industry 4.0 as an attractor for any type of relocations, might provide results useful also for the central governments.

As well as Poland, several other countries implemented some Industry 4.0 programs in years after the end of the survey period. For this reason, in order to provide more relevant data expressing the attractiveness of the Industry 4.0 policies, it would be very important to extend the survey period also for the years 2016, 2017 and 2018. In this way, the model would capture the effect, in terms of attractiveness, relative to the countries that implemented lately the Industry 4.0 plans. In particular, during these years, many eastern European countries have launched their programs. Among these, besides the already mentioned Poland, Czech Republic, Hungary and Romania are the ones that worth a mention, also because they are among the first in the ranking for the most frequent destination.

Keeping the attention on the Industry 4.0 initiatives, a further improvement on the current model may be the adding, as explanatory variable, of the relative expenditure in terms of Industry 4.0 plans of each government. Such a variable, besides discerning each country on the basis of its propensity to invest in the Industry 4.0 plans, might put in relationship the intensity of the investments with the decision to adopt a RHC over a RTC.

A further suggestion for the improvement of the model may lie in the sophistication of the variable controlling the propensity for innovation. In fact, some further investigation may be conducted on the patent databases (both the EPO or the USPTO). The in-depth investigation would distinguish, among the patents referred to the FIR, the ones effectively related to the enabling technologies. Hence, the investigation should include in the model only the patents related to CPS, IoT, Additive Manufacturing, AGVs and 5G Connectivity.

Always with regard to the innovation of the firms, a thorough analysis may include some data on the firms' side. In particular, a survey to the firms may provide the propensity to adopt the new technologies. The data might consist in the capital expenditure in the field of the

Industry 4.0-related appliances, or the degree of use of the newly adopted devices in the day-to-day production activities.

The most important sophistication necessary for the models should be the introduction of a counterfactual check on the firms that have once relocated their production activities. In fact, the model "as is", controls only the firms undertaking a RSD. There is the possibility, instead, that some firms, after transferring an activity from the home to the host country for the first time, may decide, for different reasons, not to relocate a second time. The firm, in fact, might decide not to move if in the first host country an innovative context may emerge, thanks to an Industry 4.0 initiative. Alternatively, the firm may decide not to relocate a second time, if it had adopted a large content of new technologies and exploits the advantages of these, without deciding to move towards a different destination.

Chapter 5: Concluding Remarks

The analysis of this dissertation represented an attempt to provide some evidence on the relationship between the stream of the RHC and the diffusion, both at firm level and also at country level of the new technologies.

The results obtained, offer some insights. In particular, examining the interaction between the location advantages and the two variables considering Industry 4.0 and the patents, some different conclusions may be drawn. In general, a firm with a high technological content (expressed by the number of patents) will adopt a relocation strategy based on RHC. This is confirmed, in particular, for European firms looking for cost advantages. In addition to these companies, also those ones pursuing the creation of strategic asset will return to the home country if they applied for a large number of patents. On the other hand, for the firms pursuing cost advantages and the creation of strategic assets, the RTC will be the preferred choice if in the second host country an Industry 4.0 policy is in force.

Once explained these insightful results given by the new technologies, it is possible to recap also the results obtained, for the models in which the variables of Industry 4.0 and the patents have no influence. Two different typologies of firms can be distinguished.

The firsts are the firms oriented to the expansion of the market and the expansion of the strategic assets, independently from the presence. This typology of firms is inclined for a RHC and suffered also the influence of the economic crisis of 2007-2008.

The second type of firms is more concerned with efficiency, so pursuing the reduction of the costs and the enhancing of productivity. For those firms, the RTC is the most preferred choice. Furthermore, in analyzing the two differentials, so the two regressions, there is a propensity to leave the Eastern European country and to move towards an Eastern European country.

A sophistication in the study of the technology, namely a deeper analysis on the specific devices effectively implemented, is suggested in future studies. Additionally, a thorough distinction of the Industry 4.0 initiatives on the basis of the typology or the amount government financing and the main area of competence would create a sort of distinction among the initiatives. In this way, the test would measure the effect of different levels of commitment by the central government.

Another matter in favor of the continuation of the research is the extension of the temporal horizon. In fact, in order to better capture the effect of the diffusion of the Industry 4.0 programs, the analysis should be extended also to the years 2016 and 2017. Those two years, represent, also the year of adoption of the programs for a very large number of countries.

After having traced these indications, I can define my dissertation as a starting point, for a future analysis of the relocation trends occurring all over the world, using the new technologies as an influential factor.

In conclusion, I believe that the results provided by my analysis can be considered as valid, given the partial influence of the new variables for the distinction between RSD and RHC.

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Data Sources

Variables In the regression model

Indicator	*Source*	*URL*
Market-Seeking driver	World Bank	https://data.worldbank.org/indicator/NY.GDP.MKTP.PP.KD
Asset-Seeking driver	World Bank	https://data.worldbank.org/indicator/SP.POP.SCIE.RD.P6
Cost-Reduction driver	OECD	https://data.oecd.org/lprdtv/unit-labour-costs.htm
Productivity-Enhancing driver	World Bank	https://data.worldbank.org/indicator/SL.GDP.PCAP.EM.KD
Cultural Distance	Hofstede Insights	https://www.hofstede-insights.com/product/compare-countries/

Data on Industry 4.0

The data for the Industry 4.0 initiatives are retrieved on the website of the European Commission for Growth.

Link: https://ec.europa.eu/growth/tools-databases/dem/monitor/tags/industry-40

Data on the Firms

All the data regarding the firms are extracted from the ERM data set, provided for the research purpose.

Data on the Patents

The data regarding the patents and its extraction are treated in detail in Annex 1 and Annex 2.

Annexes

Annex 1: IPC Codes in the 4IR Report by EPO

For each class is reported the description as indicated on

http://www.wipo.int/classifications/ipc/

Class A01: Agriculture; Forestry; Animal Husbandry; Hunting; Trapping; Fishing

A01B69/00	A01B69/06	A01B69/08	A01B69/04
A01B79/00	A01C21/00	A01D34/00	A01D41/127
A01D91/00	A01D91/02	A01D91/04	A01G7/04
A01G25/16	A01J5/007	A01J5/01	A01J5/017
A01K1/12	A01K11/00	A01K15/02	A01K29/00

Class A47: Furniture; Domestic Articles or Appliances; Spice Mills; Suction Cleaners

A47K5/12	A47K10/32
A47L11/40	A47G29/14

Class A61: Medical or Veterinary Science; Hygiene

A61B1/00	A61B5/00	A61B5/145	A61B6/00	A61B8/00	A61B17/00
A61B34/00	A61B34/10	A61B34/20	A61B34/32	A61B34/35	A61B34/37
A61B90/00	A61B90/90	A61B90/92	A61B90/94	A61B90/96	A61B90/98
A61C7/00	A61C13/00	A61F2/30	A61F5/00	A61H3/00	A61H3/02
A61H3/04	A61H3/06	A61H31/00	A61M16/00	A61N1/372	A61N5/10

Class A63: Sports; Games; Amusements

A63B24/00	A63B71/06	A63F9/24	A63F13/00	A63F13/98
A63F13/219	A63F13/20	A63F13/90	A63F13/40	A63F13/30
A63F13/21	A63F13/211	A63F13/212	A63F13/213	A63F13/214
A63F13/2145	A63F13/215	A63F13/216	A63F13/217	A63F13/218
A63F13/22	A63F13/23	A63F13/235	A63F13/24	A63F13/245
A63F13/25	A63F13/26	A63F13/27	A63F13/28	A63F13/285
A63F13/31	A63F13/32	A63F13/323	A63F13/327	A63F13/33
A63F13/332	A63F13/335	A63F13/338	A63F13/34	A63F13/35
A63F13/352	A63F13/355	A63F13/358	A63F13/42	A63F13/422
A63F13/424	A63F13/426	A63F13/428	A63F13/44	A63F13/45
A63F13/46	A63F13/47	A63F13/48	A63F13/49	A63F13/493
A63F13/497	A63F13/50	A63F13/52	A63F13/525	A63F13/5252
A63F13/5255	A63F13/5258	A63F13/53	A63F13/533	A63F13/537
A63F13/5372	A63F13/5375	A63F13/5378	A63F13/54	A63F13/55
A63F13/56	A63F13/57	A63F13/573	A63F13/577	A63F13/58
A63F13/60	A63F13/61	A63F13/63	A63F13/65	A63F13/655
A63F13/67	A63F13/69	A63F13/70	A63F13/71	A63F13/73
A63F13/75	A63F13/77	A63F13/79	A63F13/792	A63F13/795
A63F13/798	A63F13/80	A63F13/803	A63F13/807	A63F13/812
A63F13/814	A63F13/816	A63F13/818	A63F13/822	A63F13/825
A63F13/828	A63F13/833	A63F13/837	A63F13/843	A63F13/847
A63F13/85	A63F13/86	A63F13/87	A63F13/88	A63F13/92
A63F13/95				

Class B01: Physical or Chemical Processes or Apparatus in General
B01L3/00

Class B05: Spraying or Atomising in General; Applying liquids or other fluent Materials to surfaces in general

B05B12/00	B05B12/02	B05B12/04	B05B12/06	B05B12/08
B05B12/10	B05B12/12	B05B12/14	B05C11/10	B05C11/105

Class B60: Vehicles in General

B60C23/04	B60C25/05	B60D1/01	B60D1/02	B60D1/04	B60D1/06
B60D1/07	B60D1/24	B60D1/26	B60D1/28	B60D1/30	B60D1/32
B60D1/34	B60D1/36	B60D1/38	B60D1/40	B60D1/42	B60D1/44
B60D1/46	B60D1/48	B60D1/50	B60D1/52	B60D1/54	B60D1/56
B60H1/00	B60K28/00	B60K28/02	B60K28/04	B60K28/06	B60K28/08
B60K28/10	B60K28/12	B60K28/14	B60K28/16	B60K31/00	B60K31/02
B60K31/04	B60K31/06	B60K31/08	B60K31/10	B60K31/12	B60K31/14
B60K31/16	B60K31/18	B60K35/00	B60K37/06	B60L11/18	B60N2/00
B60N2/02	B60N2/28	B60P1/00	B60P1/02	B60P1/04	B60P1/06
B60P1/08	B60P1/10	B60P1/12	B60P1/14	B60P1/16	B60P1/18
B60P1/20	B60P1/22	B60P1/24	B60P1/26	B60P1/267	B60P1/273
B60P1/28	B60P1/30	B60P1/32	B60P1/34	B60P1/36	B60P1/38
B60P1/40	B60P1/42	B60P1/43	B60P1/44	B60P1/48	B60P1/50
B60P1/52	B60P1/54	B60P1/56	B60P1/58	B60P1/60	B60P1/62
B60P1/64	B60P3/00	B60P3/025	B60P3/03	B60P3/035	B60P3/04
B60P3/05	B60P3/055	B60P3/06	B60P3/07	B60P3/071	B60P3/073
B60P3/075	B60P3/077	B60P3/079	B60P3/08	B60P3/10	B60P3/11
B60P3/12	B60P3/14	B60P3/16	B60P3/18	B60P3/20	B60P3/22
B60P3/24	B60P3/28	B60P3/30	B60P3/32	B60P3/34	B60P3/36
B60P3/38	B60P3/39	B60P3/40	B60P3/41	B60P3/42	B60P7/00
B60P7/02	B60P7/04	B60P7/06	B60P7/08	B60P7/10	B60P7/12
B60P7/13	B60P7/135	B60P7/14	B60P7/15	B60P7/16	B60P7/18
B60P9/00	B60Q1/08	B60Q1/10	B60Q1/105	B60Q1/11	B60Q1/115
B60Q1/12	B60Q1/124	B60Q1/14	B60Q1/34	B60Q1/40	B60Q1/42
B60Q1/44	B60Q1/52	B60Q3/00	B60Q3/10	B60Q3/12	B60Q3/14
B60Q3/16	B60Q3/18	B60Q3/20	B60Q3/208	B60Q3/217	B60Q3/225
B60Q3/233	B60Q3/242	B60Q3/252	B60Q3/258	B60Q3/267	B60Q3/275
B60Q3/283	B60Q3/292	B60Q3/30	B60Q3/35	B60Q3/40	B60Q3/41
B60Q3/43	B60Q3/44	B60Q3/46	B60Q3/47	B60Q3/49	B60Q3/50
B60Q3/51	B60Q3/53	B60Q3/54	B60Q3/56	B60Q3/57	B60Q3/59
B60Q3/60	B60Q3/62	B60Q3/64	B60Q3/66	B60Q3/68	B60Q3/70
B60Q3/72	B60Q3/74	B60Q3/76	B60Q3/78	B60Q3/80	B60Q3/82
B60Q5/00	B60Q9/00	B60R25/04	B60R25/042	B60R25/043	B60R25/044
B60R25/045	B60R25/06	B60R25/08	B60R25/09	B60R25/10	B60R25/102
B60R25/104	B60R25/20	B60R25/21	B60R25/22	B60R25/23	B60R25/24
B60R25/25	B60R25/30	B60R25/31	B60R25/32	B60R25/33	B60R25/34
B60R25/40	B60S1/02	B60S1/08	B60S1/48	B60S1/56	B60S1/58
B60S1/60	B60S3/00	B60S3/04	B60S3/06	B60S5/02	B60S5/06
B60T7/12	B60T7/14	B60T7/16	B60T7/18	B60T7/20	B60T7/22
B60T8/1755	B60T13/66	B60T13/68	B60T13/70	B60T13/72	B60T13/74
B60T17/18	B60T17/20	B60T17/22	B60W10/00	B60W30/00	B60W30/02
B60W30/04	B60W30/045	B60W30/06	B60W30/08	B60W30/085	B60W30/09

B60W30/095	B60W30/10	B60W30/12	B60W30/14	B60W30/16	B60W30/165
B60W30/17	B60W30/18	B60W30/182	B60W30/184	B60W30/186	B60W30/188
B60W30/19	B60W30/192	B60W30/194	B60W30/20	B60W40/00	B60W40/02
B60W40/04	B60W40/06	B60W40/064	B60W40/068	B60W40/072	B60W40/076
B60W40/08	B60W40/09	B60W40/10	B60W40/101	B60W40/103	B60W40/105
B60W40/107	B60W40/109	B60W40/11	B60W40/112	B60W40/114	B60W40/12
B60W40/13	B60W50/00	B60W50/02	B60W50/023	B60W50/029	B60W50/032
B60W50/035	B60W50/038	B60W50/04	B60W50/06	B60W50/08	B60W50/10
B60W50/12	B60W50/14	B60W50/16			

Class B61: Railways

B61L3/00	B61L3/02	B61L3/04	B61L3/06	B61L3/08	B61L3/10
B61L3/12	B61L3/14	B61L3/16	B61L3/18	B61L3/20	B61L3/22
B61L3/24	B61L15/00	B61L15/02	B61L23/00	B61L23/02	B61L23/04
B61L23/06	B61L23/08	B61L23/10	B61L23/12	B61L23/14	B61L23/16
B61L23/18	B61L23/20	B61L23/22	B61L23/24	B61L23/26	B61L23/28
B61L23/30	B61L23/32	B61L23/34	B61L25/00	B61L25/02	B61L25/04
B61L25/06	B61L25/08	B61L27/00	B61L27/02	B61L27/04	

Class B62: Land Vehicles for Travelling otherwise than on Rails

B62D15/02	B62H3/00	B62H5/20
B62M6/45	B62M6/50	

Class B64: Aircraft; Aviation; Cosmonautics

B64C13/18	B64C13/50	B64C39/02	B64D11/00
B64D11/06	B64D45/00	B64D45/02	B64D45/04
B64D45/06	B64D45/08	B64F1/22	B64F1/36
B64F5/10	B64F5/40	B64F5/45	B64F5/60

Class B65: Conveying; Packing; Storing; Handling thin or filamentary Material

B65B57/00	B65B57/02	B65B57/04	B65B57/06
B65B57/08	B65B57/10	B65B57/12	B65B57/14
B65B57/16	B65B57/18	B65B57/20	

Class B82: Nanotechnology
B82Y10/00

Class C12: Biochemistry; Beer; Spirits; Wine; Vinegar; Microbiology; Enzymology; Mutation or Genetic Engineering
C12N5/00

Class D06: Treatment of Textiles or the Like; Laundering; Flexible Materials

D06F33/02	D06F39/00	D06F93/00	D06M13/00	D06M10/00	D06M10/02
D06M10/04	D06M10/06	D06M10/08	D06M10/10	D06M11/00	D06M11/01
D06M11/05	D06M11/07	D06M11/09	D06M11/11	D06M11/13	D06M11/155
D06M11/17	D06M11/20	D06M11/22	D06M11/24	D06M11/26	D06M11/28
D06M11/30	D06M11/32	D06M11/34	D06M11/36	D06M11/38	D06M11/40
D06M11/42	D06M11/44	D06M11/45	D06M11/46	D06M11/47	D06M11/48
D06M11/49	D06M11/50	D06M11/51	D06M11/52	D06M11/53	D06M11/54
D06M11/55	D06M11/56	D06M11/57	D06M11/58	D06M11/59	D06M11/60
D06M11/61	D06M11/62	D06M11/63	D06M11/64	D06M11/65	D06M11/66

D06M11/67	D06M11/68	D06M11/69	D06M11/70	D06M11/71	D06M11/72
D06M11/73	D06M11/74	D06M11/75	D06M11/76	D06M11/77	D06M11/78
D06M11/79	D06M11/80	D06M11/81	D06M11/82	D06M11/83	D06M11/84
D06M13/02	D06M13/03	D06M13/07	D06M13/08	D06M13/10	D06M13/11
D06M13/12	D06M13/123	D06M13/127	D06M13/13	D06M13/133	D06M13/137
D06M13/144	D06M13/148	D06M13/152	D06M13/156	D06M13/165	D06M13/17
D06M13/175	D06M13/184	D06M13/188	D06M13/192	D06M13/196	D06M13/203
D06M13/207	D06M13/21	D06M13/213	D06M13/217	D06M13/224	D06M13/228
D06M13/232	D06M13/236	D06M13/238	D06M13/244	D06M13/248	D06M13/252
D06M13/256	D06M13/262	D06M13/265	D06M13/268	D06M13/272	D06M13/275
D06M13/278	D06M13/282	D06M13/285	D06M13/288	D06M13/29	D06M13/292
D06M13/295	D06M13/298	D06M13/313	D06M13/322	D06M13/325	D06M13/328
D06M13/33	D06M13/332	D06M13/335	D06M13/338	D06M13/342	D06M13/345
D06M13/348	D06M13/35	D06M13/352	D06M13/355	D06M13/358	D06M13/364
D06M13/368	D06M13/372	D06M13/376	D06M13/382	D06M13/385	D06M13/388
D06M13/392	D06M13/395	D06M13/398	D06M13/402	D06M13/405	D06M13/408
D06M13/41	D06M13/412	D06M13/415	D06M13/418	D06M13/419	D06M13/422
D06M13/425	D06M13/428	D06M13/432	D06M13/435	D06M13/438	D06M13/44
D06M13/447	D06M13/453	D06M13/46	D06M13/463	D06M13/467	D06M13/47
D06M13/473	D06M13/477	D06M13/48	D06M13/487	D06M13/493	D06M13/50
D06M13/503	D06M13/507	D06M13/51	D06M13/513	D06M13/517	D06M13/52
D06M13/525	D06M13/53	D06M13/535	D06M14/00	D06M14/02	D06M14/04
D06M14/06	D06M14/08	D06M14/10	D06M14/12	D06M14/14	D06M14/16
D06M14/18	D06M14/20	D06M14/22	D06M14/24	D06M14/26	D06M14/28
D06M14/30	D06M14/32	D06M14/34	D06M14/36	D06M15/00	D06M15/01
D06M15/03	D06M15/05	D06M15/055	D06M15/07	D06M15/09	D06M15/11
D06M15/13	D06M15/15	D06M15/17	D06M15/19	D06M15/21	D06M15/227
D06M15/233	D06M15/244	D06M15/248	D06M15/252	D06M15/256	D06M15/263
D06M15/267	D06M15/27	D06M15/273	D06M15/277	D06M15/285	D06M15/29
D06M15/295	D06M15/31	D06M15/327	D06M15/33	D06M15/333	D06M15/347
D06M15/353	D06M15/356	D06M15/37	D06M15/39	D06M15/41	D06M15/415
D06M15/423	D06M15/427	D06M15/429	D06M15/43	D06M15/431	D06M15/432
D06M15/433	D06M15/437	D06M15/45	D06M15/507	D06M15/51	D06M15/513
D06M15/53	D06M15/55	D06M15/555	D06M15/564	D06M15/568	D06M15/572
D06M15/576	D06M15/579	D06M15/59	D06M15/592	D06M15/595	D06M15/598
D06M15/61	D06M15/63	D06M15/643	D06M15/647	D06M15/65	D06M15/653
D06M15/657	D06M15/667	D06M15/673	D06M15/687	D06M15/693	D06M15/70
D06M15/705	D06M15/71	D06M15/715	D06M16/00	D06M17/00	D06M17/02
D06M17/04	D06M17/06	D06M17/08	D06M17/10	D06M19/00	D06M23/00
D06M23/02	D06M23/04	D06M23/06	D06M23/08	D06M23/10	D06M23/12
D06M23/14	D06M23/16	D06M23/18	D06N7/00	D06P7/00	D06Q1/00
D06Q1/02	D06Q1/04	D06Q1/06	D06Q1/08	D06Q1/10	D06Q1/12
D06Q1/14					

Class E01: Construction of Roads Railways or Bridges

E01C19/00	E01F9/40	E04H6/42

Class E05: Locks; Keys; Window or door Fittings; Safes

E05B35/00	E05B47/00	E05B49/00	E05B65/10	E05B77/00
E05B77/02	E05B77/04	E05B77/06	E05B77/08	E05B77/10
E05B77/12	E05B77/14	E05B77/16	E05B77/18	E05B77/20
E05B77/22	E05B77/24	E05B77/26	E05B77/28	E05B77/30

E05B77/32	E05B77/34	E05B77/36	E05B77/38	E05B77/40
E05B77/42	E05B77/44	E05B77/46	E05B77/48	E05B77/50
E05B77/52	E05B77/54	E05C17/58	E05F15/77	

Class E21: Earth or Rock Drilling; Mining

E21B44/00	E21B44/02	E21B44/04	E21B44/06	E21B44/08
E21B44/10	E21B47/12	E21B47/14	E21B47/16	E21B47/18

Class F01: Machines or Engines in General; Engine Plants in General; Steam Engines

F01B25/00	F01B25/02	F01B25/04	F01B25/06	F01B25/08
F01B25/10	F01B25/12	F01B25/14	F01B25/16	F01B25/18
F01B25/20	F01B25/22	F01B25/24	F01B25/26	F01C20/00
F01C20/02	F01C20/04	F01C20/06	F01C20/08	F01C20/10
F01C20/12	F01C20/14	F01C20/16	F01C20/18	F01C20/20
F01C20/22	F01C20/24	F01C20/26	F01C20/28	F01D17/00
F01D21/00	F01D21/20	F01K13/02	F01N9/00	F01N11/00

Class F02:

F02C9/00	F02C9/16	F02C9/18	F02C9/20	F02C9/22	F02C9/24
F02C9/26	F02C9/28	F02C9/30	F02C9/32	F02C9/34	F02C9/36
F02C9/38	F02C9/40	F02C9/42	F02C9/44	F02C9/46	F02C9/48
F02C9/50	F02C9/52	F02C9/54	F02C9/56	F02C9/58	F02D1/00
F02D1/02	F02D1/04	F02D1/06	F02D1/08	F02D1/10	F02D1/12
F02D1/14	F02D1/16	F02D1/18	F02D3/00	F02D3/02	F02D3/04
F02D7/00	F02D7/02	F02D9/00	F02D9/02	F02D9/04	F02D9/06
F02D9/08	F02D9/10	F02D9/12	F02D9/14	F02D9/16	F02D9/18
F02D11/00	F02D11/02	F02D11/04	F02D11/06	F02D11/08	F02D11/10
F02D13/00	F02D13/02	F02D13/04	F02D13/06	F02D13/08	F02D15/00
F02D15/02	F02D15/04	F02D17/00	F02D17/02	F02D17/04	F02D19/00
F02D19/02	F02D19/04	F02D19/06	F02D19/08	F02D19/10	F02D19/12
F02D21/00	F02D21/02	F02D21/04	F02D21/06	F02D21/08	F02D21/10
F02D23/00	F02D23/02	F02D25/00	F02D25/02	F02D25/04	F02D27/00
F02D27/02	F02D28/00	F02D29/00	F02D29/02	F02D29/04	F02D29/06
F02D31/00	F02D33/00	F02D33/02	F02D35/00	F02D35/02	F02D37/00
F02D37/02	F02D39/00	F02D39/02	F02D39/04	F02D39/06	F02D39/08
F02D39/10	F02D41/00	F02D41/02	F02D41/04	F02D41/06	F02D41/08
F02D41/10	F02D41/12	F02D41/14	F02D41/16	F02D41/18	F02D41/20
F02D41/22	F02D41/24	F02D41/26	F02D41/28	F02D41/30	F02D41/32
F02D41/34	F02D41/36	F02D41/38	F02D41/40	F02K9/00	F02K9/08
F02K9/10	F02K9/12	F02K9/14	F02K9/16	F02K9/18	F02K9/20
F02K9/22	F02K9/24	F02K9/26	F02K9/28	F02K9/30	F02K9/32
F02K9/34	F02K9/36	F02K9/38	F02K9/40	F02K9/42	F02K9/44
F02K9/46	F02K9/48	F02K9/50	F02K9/52	F02K9/54	F02K9/56
F02K9/58	F02K9/60	F02K9/62	F02K9/64	F02K9/66	F02K9/68
F02K9/70	F02K9/72	F02K9/74	F02K9/76	F02K9/78	F02K9/80
F02K9/82	F02K9/84	F02K9/86	F02K9/88	F02K9/90	F02K9/92
F02K9/94	F02K9/95	F02K9/96	F02K9/97	F02N11/08	F02P5/00
F02P5/02	F02P5/04	F02P5/05	F02P5/06	F02P5/07	F02P5/10
F02P5/12	F02P5/14	F02P5/145	F02P5/15	F02P5/152	F02P5/153
F02P5/155					

Class F03: Machines or Engines for Liquids, Wind, Spring, or weight Motors; Producing Mechanical Power or a Reactive Propulsive Thrust

F03B15/00	F03B15/02	F03B15/04	F03B15/06	F03B15/08	F03B15/10
F03B15/12	F03B15/14	F03B15/16	F03B15/18	F03B15/20	F03B15/22
F03B17/00	F03D7/04				

Class F04: Positive-Displacement Machines for Liquids; pumps for Liquids or Elastic Fluids

F04B49/06	F04B51/00	F04C14/00	F04C14/02	F04C14/04	F04C14/06
F04C14/08	F04C14/10	F04C14/12	F04C14/14	F04C14/16	F04C14/18
F04C14/20	F04C14/22	F04C14/24	F04C14/26	F04C14/28	F04C28/00
F04C28/02	F04C28/04	F04C28/06	F04C28/08	F04C28/10	F04C28/12
F04C28/14	F04C28/16	F04C28/18	F04C28/20	F04C28/22	F04C28/24
F04C28/26	F04C28/28	F04D27/00	F04D27/02		

Class F16: Engineering Elements or Units; General Measures for Producing and Maintaing Effective Functioning of Machines or Installations; Thermal Insulation in General

F16D66/00	F16D66/02	F16H59/66	F16K37/00	F16K99/00
F16M11/18	F16P3/14			

Class F22: Steam Generation

F22B35/00	F22B35/02	F22B35/04	F22B35/06	F22B35/08	F22B35/10
F22B35/12	F22B35/14	F22B35/16	F22B35/18	F22D5/26	F22D5/28
F22D5/30	F22D5/32	F22D5/34	F22D5/36		

Class F23: Combustion Apparatus; Combustion processes

F23N5/00	F23N5/02	F23N5/04	F23N5/06	F23N5/08	F23N5/10
F23N5/12	F23N5/14	F23N5/16	F23N5/18	F23N5/20	F23N5/22
F23N5/24	F23N5/26				

Class F24: Heating; Ranges; Ventilating

F24D19/10	F24F11/00

Class F25: Refrigeration or Cooling; Combined heating and refrigeration systems; Heat pump systems; Manufacture or storage of Ice; Liquefaction or Solidification of gases

F25B49/00	F25B49/02	F25B49/04
F25D21/00	F25D29/00	F25J1/02

Class F26: Drying

F28F27/00	F28F27/02

Class G01: Measuring; Testing

G01C21/20	G01C21/22	G01C21/24	G01C21/26	G01C21/28	G01C21/30
G01C21/32	G01C21/34	G01C21/36	G01S1/00	G01S1/02	G01S1/04
G01S1/06	G01S1/08	G01S1/10	G01S1/12	G01S1/14	G01S1/16
G01S1/18	G01S1/20	G01S1/22	G01S1/24	G01S1/26	G01S1/28
G01S1/30	G01S1/32	G01S1/34	G01S1/36	G01S1/38	G01S1/40
G01S1/42	G01S1/44	G01S1/46	G01S1/48	G01S1/50	G01S1/52
G01S1/54	G01S1/56	G01S1/58	G01S1/60	G01S1/62	G01S1/64
G01S1/66	G01S1/68	G01S1/70	G01S1/72	G01S1/74	G01S1/76
G01S1/78	G01S1/80	G01S1/82	G01S3/00	G01S3/02	G01S3/04

G01S3/06	G01S3/08	G01S3/10	G01S3/12	G01S3/14	G01S3/16
G01S3/18	G01S3/20	G01S3/22	G01S3/24	G01S3/26	G01S3/28
G01S3/30	G01S3/32	G01S3/34	G01S3/36	G01S3/38	G01S3/40
G01S3/42	G01S3/44	G01S3/46	G01S3/48	G01S3/50	G01S3/52
G01S3/54	G01S3/56	G01S3/58	G01S3/60	G01S3/62	G01S3/64
G01S3/66	G01S3/68	G01S3/70	G01S3/72	G01S3/74	G01S3/78
G01S3/781	G01S3/782	G01S3/783	G01S3/784	G01S3/785	G01S3/786
G01S3/787	G01S3/788	G01S3/789	G01S3/80	G01S3/801	G01S3/802
G01S3/803	G01S3/805	G01S3/807	G01S3/808	G01S3/809	G01S3/82
G01S3/84	G01S3/86	G01S5/00	G01S5/02	G01S5/04	G01S5/06
G01S5/08	G01S5/10	G01S5/12	G01S5/14	G01S5/16	G01S5/18
G01S5/20	G01S5/22	G01S5/24	G01S5/26	G01S5/28	G01S5/30
G01S7/00	G01S11/00	G01S13/86	G01S13/87	G01S13/93	G01S15/02
G01S15/87	G01S15/89	G01S15/93	G01S17/02	G01S17/87	G01S17/93
G01S17/95	G01S19/00	G01S19/01	G01S19/02	G01S19/03	G01S19/04
G01S19/05	G01S19/06	G01S19/07	G01S19/08	G01S19/09	G01S19/10
G01S19/11	G01S19/12	G01S19/13	G01S19/14	G01S19/15	G01S19/16
G01S19/17	G01S19/18	G01S19/19	G01S19/20	G01S19/21	G01S19/22
G01S19/23	G01S19/24	G01S19/25	G01S19/26	G01S19/27	G01S19/28
G01S19/29	G01S19/30	G01S19/31	G01S19/32	G01S19/33	G01S19/34
G01S19/35	G01S19/36	G01S19/37	G01S19/38	G01S19/39	G01S19/40
G01S19/41	G01S19/42	G01S19/43	G01S19/44	G01S19/45	G01S19/46
G01S19/47	G01S19/48	G01S19/49	G01S19/50	G01S19/51	G01S19/52
G01S19/53	G01S19/54	G01S19/55			

Class G02: Optics
G02B27/01

Class G03: Photography; Cinematography; Analogous Techniques using wavers other than optical waves; Electrography Holography

G03G15/00	G03G15/01	G03G15/02	G03G15/04	G03G15/041	G03G15/043
G03G15/045	G03G15/047	G03G15/05	G03G15/054	G03G15/056	G03G15/06
G03G15/08	G03G15/09	G03G15/095	G03G15/10	G03G15/11	G03G15/14
G03G15/16	G03G15/18	G03G15/20	G03G15/22	G03G15/23	G03G15/24
G03G15/26	G03G15/28	G03G15/30	G03G15/32	G03G15/34	G03G15/36

Class G04: Horology

G04G21/00	G04G21/02	G04G21/04	G04G21/06	G04G21/08

Class G05: Controlling; Regulating

G05B15/00	G05B15/02	G05B23/02	G05D1/00	G05D1/02	G05D1/03
G05D1/04	G05D1/06	G05D1/08	G05D1/10	G05D1/12	G05D23/19
G05D23/20	G05D23/22	G05D23/24	G05D23/26	G05D23/27	G05D23/275
G05D23/30	G05D23/32				

Class G06: Computing; Calculating; Counting

G06F1/20	G06F1/32	G06F3/00	G06F3/01	G06F3/02	G06F3/023
G06F3/027	G06F3/03	G06F3/033	G06F3/0338	G06F3/0346	G06F3/0354
G06F3/0362	G06F3/037	G06F3/038	G06F3/039	G06F3/041	G06F3/042
G06F3/043	G06F3/044	G06F3/045	G06F3/046	G06F3/047	G06F3/048
G06F3/0481	G06F3/0482	G06F3/0483	G06F3/0484	G06F3/0485	G06F3/0486

G06F3/0487	G06F3/0488	G06F3/0489	G06F3/05	G06F3/06	G06F3/14
G06F3/147	G06F3/153	G06F8/00	G06F8/10	G06F8/20	G06F8/30
G06F8/33	G06F8/34	G06F8/35	G06F8/36	G06F8/38	G06F8/40
G06F8/41	G06F8/51	G06F8/52	G06F8/53	G06F8/54	G06F8/60
G06F8/61	G06F8/65	G06F8/654	G06F8/656	G06F8/658	G06F8/70
G06F8/71	G06F8/72	G06F8/73	G06F8/74	G06F8/75	G06F8/76
G06F8/77	G06F9/00	G06F9/02	G06F9/04	G06F9/06	G06F9/22
G06F9/24	G06F9/26	G06F9/28	G06F9/30	G06F9/32	G06F9/34
G06F9/345	G06F9/35	G06F9/355	G06F9/38	G06F9/44	G06F9/4401
G06F9/445	G06F9/448	G06F9/451	G06F9/455	G06F9/46	G06F9/48
G06F9/50	G06F9/52	G06F9/54	G06F11/08	G06F11/10	G06F11/14
G06F11/16	G06F11/18	G06F11/20	G06F12/00	G06F12/02	G06F12/04
G06F12/06	G06F12/08	G06F12/0802	G06F12/0804	G06F12/0806	G06F12/0808
G06F12/0811	G06F12/0813	G06F12/0815	G06F12/0817	G06F12/0831	G06F12/0837
G06F12/084	G06F12/0842	G06F12/0844	G06F12/0846	G06F12/0853	G06F12/0855
G06F12/0862	G06F12/0864	G06F12/0866	G06F12/0868	G06F12/0871	G06F12/0873
G06F12/0875	G06F12/0877	G06F12/0879	G06F12/0882	G06F12/0884	G06F12/0886
G06F12/0888	G06F12/0891	G06F12/0893	G06F12/0895	G06F12/0897	G06F12/10
G06F12/1009	G06F12/1018	G06F12/1027	G06F12/1036	G06F12/1045	G06F12/1072
G06F12/1081	G06F12/109	G06F12/12	G06F12/121	G06F12/122	G06F12/123
G06F12/126	G06F12/127	G06F12/128	G06F12/14	G06F17/00	G06F17/10
G06F17/11	G06F17/12	G06F17/13	G06F17/14	G06F17/15	G06F17/16
G06F17/17	G06F17/18	G06F17/20	G06F17/21	G06F17/22	G06F17/24
G06F17/25	G06F17/26	G06F17/27	G06F17/28	G06F17/30	G06F17/40
G06F17/50	G06F19/10	G06F19/12	G06F19/14	G06F19/16	G06F19/18
G06F19/20	G06F19/22	G06F19/24	G06F19/26	G06F19/28	G06F19/00
G06F21/00	G06F21/10	G06F21/12	G06F21/14	G06F21/16	G06F21/30
G06F21/31	G06F21/32	G06F21/33	G06F21/34	G06F21/35	G06F21/36
G06F21/40	G06F21/41	G06F21/42	G06F21/43	G06F21/44	G06F21/45
G06F21/46	G06F21/50	G06F21/51	G06F21/52	G06F21/53	G06F21/54
G06F21/55	G06F21/56	G06F21/57	G06F21/60	G06F21/62	G06F21/64
G06F21/70	G06F21/71	G06F21/72	G06F21/73	G06F21/74	G06F21/75
G06F21/76	G06F21/77	G06F21/78	G06F21/79	G06F21/80	G06F21/81
G06F21/82	G06F21/83	G06F21/84	G06F21/85	G06F21/86	G06F21/87
G06F21/88	G06K1/00	G06K1/02	G06K1/04	G06K1/05	G06K1/06
G06K1/08	G06K1/10	G06K1/12	G06K1/14	G06K1/16	G06K1/18
G06K1/20	G06K1/22	G06K3/00	G06K3/02	G06K5/00	G06K5/02
G06K5/04	G06K7/00	G06K7/01	G06K7/015	G06K7/016	G06K7/02
G06K7/04	G06K7/06	G06K7/08	G06K7/10	G06K7/12	G06K7/14
G06K9/00	G06K9/03	G06K9/18	G06K9/20	G06K9/22	G06K9/24
G06K9/26	G06K9/28	G06K9/30	G06K9/32	G06K9/34	G06K9/36
G06K9/38	G06K9/40	G06K9/42	G06K9/44	G06K9/46	G06K9/48
G06K9/50	G06K9/52	G06K9/54	G06K9/56	G06K9/58	G06K9/60
G06K9/62	G06K9/64	G06K9/66	G06K9/68	G06K9/70	G06K9/72
G06K9/74	G06K9/76	G06K9/78	G06K9/80	G06K9/82	G06K11/00
G06K11/02	G06K11/04	G06K11/06	G06K13/00	G06K13/02	G06K13/04
G06K13/05	G06K13/06	G06K13/063	G06K13/067	G06K13/07	G06K13/073
G06K13/077	G06K13/08	G06K13/10	G06K13/103	G06K13/107	G06K13/12
G06K13/14	G06K13/16	G06K13/18	G06K13/20	G06K13/22	G06K13/24
G06K13/26	G06K13/28	G06K13/30	G06K15/00	G06K15/02	G06K15/04
G06K15/06	G06K15/07	G06K15/08	G06K15/10	G06K15/12	G06K15/14
G06K15/16	G06K15/22	G06K17/00	G06K19/00	G06K19/02	G06K19/04
G06K19/06	G06K19/063	G06K19/067	G06K19/07	G06K19/073	G06K19/077

G06K19/08	G06K19/10	G06K19/12	G06K19/14	G06K19/16	G06K19/18
G06K21/00	G06K21/02	G06K21/04	G06K21/06	G06K21/08	G06N3/00
G06N3/02	G06N3/04	G06N3/06	G06N3/063	G06N3/067	G06N3/08
G06N3/10	G06N3/12	G06N5/00	G06N5/02	G06N5/04	G06N7/00
G06N7/02	G06N7/04	G06N7/06	G06N7/08	G06N99/00	G06Q10/00
G06Q10/02	G06Q10/04	G06Q10/06	G06Q10/08	G06Q10/10	G06Q20/00
G06Q20/02	G06Q20/04	G06Q20/06	G06Q20/08	G06Q20/10	G06Q20/12
G06Q20/14	G06Q20/16	G06Q20/18	G06Q20/20	G06Q20/22	G06Q20/24
G06Q20/26	G06Q20/28	G06Q20/30	G06Q20/32	G06Q20/34	G06Q20/36
G06Q20/38	G06Q20/40	G06Q20/42	G06Q30/00	G06Q30/02	G06Q30/04
G06Q30/06	G06Q30/08	G06Q40/00	G06Q40/02	G06Q40/04	G06Q40/06
G06Q40/08	G06Q50/02	G06Q50/06	G06Q50/22	G06Q50/30	

Class G07: Checking-Devices

G07B15/00	G07B15/02	G07B15/04	G07B15/06	G07C5/00	G07C9/00

Class G08: Signalling

G08B1/00	G08B1/02	G08B1/04	G08B1/06	G08B1/08	G08B3/00
G08B3/02	G08B3/06	G08B3/10	G08B3/14	G08B5/00	G08B5/02
G08B5/06	G08B5/14	G08B5/16	G08B5/18	G08B5/20	G08B5/22
G08B5/24	G08B5/26	G08B5/28	G08B5/30	G08B5/32	G08B5/34
G08B5/36	G08B5/38	G08B5/40	G08B6/00	G08B7/00	G08B7/02
G08B7/04	G08B7/06	G08B7/08	G08B9/00	G08B9/02	G08B9/04
G08B9/06	G08B9/08	G08B9/10	G08B9/12	G08B9/14	G08B9/16
G08B9/18	G08B9/20	G08B13/00	G08B13/02	G08B13/04	G08B13/06
G08B13/08	G08B13/10	G08B13/12	G08B13/14	G08B13/16	G08B13/18
G08B13/181	G08B13/183	G08B13/184	G08B13/186	G08B13/187	G08B13/189
G08B13/19	G08B13/191	G08B13/193	G08B13/194	G08B13/196	G08B13/20
G08B13/22	G08B13/24	G08B13/26	G08B15/00	G08B15/02	G08B17/00
G08B17/02	G08B17/04	G08B17/06	G08B17/08	G08B17/10	G08B17/103
G08B17/107	G08B17/11	G08B17/113	G08B17/117	G08B17/12	G08B19/00
G08B19/02	G08B21/00	G08B21/02	G08B21/04	G08B21/06	G08B21/08
G08B21/10	G08B21/12	G08B21/14	G08B21/16	G08B21/18	G08B21/20
G08B21/22	G08B21/24	G08B23/00	G08B25/00	G08B25/01	G08B25/04
G08B25/06	G08B25/08	G08B25/10	G08B25/12	G08B25/14	G08B26/00
G08B27/00	G08B29/00	G08B29/02	G08B29/04	G08B29/06	G08B29/08
G08B29/10	G08B29/12	G08B29/14	G08B29/16	G08B29/18	G08B29/20
G08B29/22	G08B29/24	G08B29/26	G08B29/28	G08B31/00	G08G1/00
G08G1/005	G08G1/01	G08G1/015	G08G1/017	G08G1/02	G08G1/04
G08G1/042	G08G1/048	G08G1/052	G08G1/054	G08G1/056	G08G1/065
G08G1/07	G08G1/08	G08G1/081	G08G1/082	G08G1/083	G08G1/085
G08G1/087	G08G1/09	G08G1/095	G08G1/0955	G08G1/096	G08G1/0962
G08G1/0965	G08G1/0967	G08G1/0968	G08G1/0969	G08G1/097	G08G1/123
G08G1/127	G08G1/13	G08G1/133	G08G1/137	G08G1/14	G08G1/16

Class G09: Educating; Cryptography; Display; Advertising; Seals

G09B1/00	G09B1/02	G09B1/04	G09B1/06	G09B1/08	G09B1/10
G09B1/12	G09B1/14	G09B1/16	G09B1/18	G09B1/20	G09B1/22
G09B1/24	G09B1/26	G09B1/28	G09B1/30	G09B1/32	G09B1/34
G09B1/36	G09B1/38	G09B1/40	G09B3/00	G09B3/02	G09B3/04
G09B3/06	G09B3/08	G09B3/10	G09B3/12	G09B5/00	G09B5/02
G09B5/04	G09B5/06	G09B5/08	G09B5/10	G09B5/12	G09B5/14

G09B7/00	G09B7/02	G09B7/04	G09B7/06	G09B7/07	G09B7/073
G09B7/077	G09B7/08	G09B7/10	G09B7/12	G09B9/00	G09B9/02
G09B9/04	G09B9/042	G09B9/048	G09B9/05	G09B9/052	G09B9/058
G09B9/06	G09B9/08	G09B9/10	G09B9/12	G09B9/14	G09B9/16
G09B9/18	G09B9/20	G09B9/22	G09B9/24	G09B9/26	G09B9/28
G09B9/30	G09B9/32	G09B9/34	G09B9/36	G09B9/38	G09B9/40
G09B9/42	G09B9/44	G09B9/46	G09B9/48	G09B9/50	G09B9/52
G09B9/54	G09B9/56	G09B11/00	G09B11/02	G09B11/04	G09B11/06
G09B11/08	G09B11/10	G09B13/00	G09B13/02	G09B13/04	G09B15/00
G09B15/02	G09B15/04	G09B15/06	G09B15/08	G09B17/00	G09B17/02
G09B17/04	G09B19/00	G09B19/02	G09B19/04	G09B19/06	G09B19/08
G09B19/10	G09B19/12	G09B19/14	G09B19/16	G09B19/18	G09B19/20
G09B19/22	G09B19/24	G09B19/26	G09B21/00	G09B21/02	G09B21/04
G09B21/06	G09B23/00	G09B23/02	G09B23/04	G09B23/06	G09B23/08
G09B23/10	G09B23/12	G09B23/14	G09B23/16	G09B23/18	G09B23/20
G09B23/22	G09B23/24	G09B23/26	G09B23/28	G09B23/30	G09B23/32
G09B23/34	G09B23/36	G09B23/38	G09B23/40	G09B25/00	G09B25/02
G09B25/04	G09B25/06	G09B25/08	G09B27/00	G09B27/02	G09B27/04
G09B27/06	G09B27/08	G09B29/00	G09B29/02	G09B29/04	G09B29/06
G09B29/08	G09B29/10	G09B29/12	G09B29/14	G09G1/00	G09G1/02
G09G1/04	G09G1/06	G09G1/07	G09G1/08	G09G1/10	G09G1/12
G09G1/14	G09G1/16	G09G1/18	G09G1/20	G09G1/22	G09G1/24
G09G1/26	G09G1/28	G09G3/00	G09G3/02	G09G3/04	G09G3/06
G09G3/08	G09G3/10	G09G3/12	G09G3/14	G09G3/16	G09G3/18
G09G3/19	G09G3/20	G09G3/22	G09G3/24	G09G3/26	G09G3/28
G09G3/2807	G09G3/2813	G09G3/282	G09G3/285	G09G3/288	G09G3/29
G09G3/291	G09G3/292	G09G3/293	G09G3/294	G09G3/296	G09G3/297
G09G3/298	G09G3/299	G09G3/30	G09G3/32	G09G3/3208	G09G3/3216
G09G3/3225	G09G3/3233	G09G3/3241	G09G3/325	G09G3/3258	G09G3/3266
G09G3/3275	G09G3/3283	G09G3/3291	G09G3/34	G09G3/36	G09G3/38
G09G5/00	G09G5/02	G09G5/04	G09G5/06	G09G5/08	G09G5/10
G09G5/12	G09G5/14	G09G5/16	G09G5/18	G09G5/20	G09G5/22
G09G5/24	G09G5/26	G09G5/28	G09G5/30	G09G5/32	G09G5/34
G09G5/36	G09G5/37	G09G5/373	G09G5/377	G09G5/38	G09G5/39
G09G5/391	G09G5/393	G09G5/395	G09G5/397	G09G5/399	G09G5/40
G09G5/42					

Class G10: Musical Instruments; Acoustics

G10H1/00	G10H1/02	G10H1/04	G10H1/043	G10H1/045	G10H1/047
G10H1/053	G10H1/055	G10H1/057	G10H1/06	G10H1/08	G10H1/10
G10H1/12	G10H1/14	G10H1/16	G10H1/18	G10H1/20	G10H1/22
G10H1/24	G10H1/26	G10H1/28	G10H1/30	G10H1/32	G10H1/34
G10H1/36	G10H1/38	G10H1/40	G10H1/42	G10H1/44	G10H1/46
G10H3/00	G10H3/02	G10H3/03	G10H3/06	G10H3/08	G10H3/09
G10H3/10	G10H3/12	G10H3/14	G10H3/16	G10H3/18	G10H3/20
G10H3/22	G10H3/24	G10H3/26	G10L15/00	G10L15/01	G10L15/02
G10L15/04	G10L15/05	G10L15/06	G10L15/065	G10L15/07	G10L15/08
G10L15/10	G10L15/12	G10L15/14	G10L15/16	G10L15/18	G10L15/183
G10L15/187	G10L15/19	G10L15/193	G10L15/197	G10L15/20	G10L15/22
G10L15/24	G10L15/25	G10L15/26	G10L15/28	G10L15/30	G10L15/32
G10L15/34					

Class H02: Generation; Conversion or Distribution or Electric Power
H02J13/00

Class H03: Basic Electronic Circuitry

H03K19/00
H03K19/003
H03K19/177
H03K19/18
H03K21/00
H03K21/02
H03K21/08
H03K21/10

Class H04: Electric Communication Technique

H04B7/26	H04L9/00	H04L9/06	H04L9/08	H04L9/10	H04L9/12
H04L9/14	H04L9/16	H04L9/30	H04L9/32	H04L9/34	H04L9/36
H04L9/38	H04L12/28	H04L29/12	H04L29/06	H04L29/08	H04L29/14
H04M1/00	H04M1/02	H04M1/03	H04M1/04	H04M1/05	H04M1/06
H04M1/08	H04M1/10	H04M1/11	H04M1/12	H04M1/13	H04M1/14
H04M1/15	H04M1/17	H04M1/18	H04M1/19	H04M1/20	H04M1/21
H04M1/215	H04M1/22	H04M1/23	H04M1/24	H04M1/247	H04M1/253
H04M1/26	H04M1/27	H04M1/272	H04M1/274	H04M1/2745	H04M1/275
H04M1/2755	H04M1/276	H04M1/278	H04M1/30	H04M1/31	H04M1/315
H04M1/32	H04M1/34	H04M1/38	H04M1/40	H04M1/50	H04M1/515
H04M1/52	H04M1/53	H04M1/54	H04M1/56	H04M1/57	H04M1/58
H04M1/60	H04M1/62	H04M1/64	H04M1/65	H04M1/652	H04M1/654
H04M1/656	H04M1/658	H04M1/66	H04M1/663	H04M1/665	H04M1/667
H04M1/67	H04M1/673	H04M1/675	H04M1/677	H04M1/68	H04M1/70
H04M1/72	H04M1/723	H04M1/725	H04M1/727	H04M1/73	H04M1/733
H04M1/737	H04M1/738	H04M1/74	H04M1/76	H04M1/78	H04M1/80
H04M1/82	H04M11/00	H04M11/02	H04M11/04	H04M11/06	H04M11/08
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H04N5/78	H04N5/781	H04N5/782	H04N5/7822	H04N5/7824	H04N5/7826
H04N5/7828	H04N5/783	H04N5/784	H04N5/80	H04N5/82	H04N5/83
H04N5/84	H04N5/85	H04N5/87	H04N5/89	H04N5/90	H04N5/903
H04N5/907	H04N5/91	H04N5/911	H04N5/913	H04N5/915	H04N5/917
H04N5/919	H04N5/92	H04N5/921	H04N5/923	H04N5/926	H04N5/928
H04N5/93	H04N5/931	H04N5/932	H04N5/935	H04N5/937	H04N5/94
H04N5/945	H04N5/95	H04N5/953	H04N5/956	H04N7/18	H04N17/00
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H04N19/134	H04N19/136	H04N19/137	H04N19/139	H04N19/14	H04N19/142
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H04N19/156	H04N19/157	H04N19/159	H04N19/16	H04N19/162	H04N19/164
H04N19/166	H04N19/167	H04N19/169	H04N19/17	H04N19/172	H04N19/174
H04N19/176	H04N19/177	H04N19/179	H04N19/18	H04N19/182	H04N19/184
H04N19/186	H04N19/187	H04N19/189	H04N19/19	H04N19/192	H04N19/194
H04N19/196	H04N19/20	H04N19/21	H04N19/23	H04N19/25	H04N19/27
H04N19/29	H04N19/30	H04N19/31	H04N19/33	H04N19/34	H04N19/36
H04N19/37	H04N19/39	H04N19/40	H04N19/42	H04N19/423	H04N19/426

H04N19/43	H04N19/433	H04N19/436	H04N19/44	H04N19/46	H04N19/463
H04N19/467	H04N19/48	H04N19/50	H04N19/503	H04N19/507	H04N19/51
H04N19/513	H04N19/517	H04N19/52	H04N19/523	H04N19/527	H04N19/53
H04N19/533	H04N19/537	H04N19/54	H04N19/543	H04N19/547	H04N19/55
H04N19/553	H04N19/557	H04N19/56	H04N19/563	H04N19/567	H04N19/57
H04N19/573	H04N19/577	H04N19/58	H04N19/583	H04N19/587	H04N19/59
H04N19/593	H04N19/597	H04N19/60	H04N19/61	H04N19/615	H04N19/62
H04N19/625	H04N19/63	H04N19/635	H04N19/64	H04N19/645	H04N19/65
H04N19/66	H04N19/67	H04N19/68	H04N19/69	H04N19/70	H04N19/80
H04N19/82	H04N19/85	H04N19/86	H04N19/87	H04N19/88	H04N19/89
H04N19/895	H04N19/90	H04N19/91	H04N19/93	H04N19/94	H04N19/96
H04N19/97	H04N19/98	H04N21/40	H04N21/41	H04N21/414	H04N21/4143
H04N21/4147	H04N21/418	H04N21/4185	H04N21/422	H04N21/4223	H04N21/4227
H04N21/426	H04N21/43	H04N21/431	H04N21/432	H04N21/433	H04N21/4335
H04N21/434	H04N21/435	H04N21/436	H04N21/4363	H04N21/4367	H04N21/437
H04N21/438	H04N21/4385	H04N21/439	H04N21/44	H04N21/4402	H04N21/4405
H04N21/4408	H04N21/441	H04N21/4415	H04N21/442	H04N21/4425	H04N21/443
H04N21/45	H04N21/454	H04N21/4545	H04N21/458	H04N21/462	H04N21/4623
H04N21/4627	H04N21/466	H04N21/47	H04N21/472	H04N21/4722	H04N21/4725
H04N21/4728	H04N21/475	H04N21/478	H04N21/4782	H04N21/4784	H04N21/4786
H04N21/4788	H04R1/00	H04R1/02	H04R1/04	H04R1/06	H04R1/08
H04R1/10	H04R1/12	H04R1/14	H04R1/16	H04R1/18	H04R1/20
H04R1/22	H04R1/24	H04R1/26	H04R1/28	H04R1/30	H04R1/32
H04R1/34	H04R1/36	H04R1/38	H04R1/40	H04R1/42	H04R1/44
H04R1/46	H04R3/00	H04R3/02	H04R3/04	H04R3/06	H04R3/08
H04R3/10	H04R3/12	H04R3/14	H04R5/00	H04R5/02	H04R5/027
H04R5/033	H04R5/04	H04R7/00	H04R7/02	H04R7/04	H04R7/06
H04R7/08	H04R7/10	H04R7/12	H04R7/14	H04R7/16	H04R7/18
H04R7/20	H04R7/22	H04R7/24	H04R7/26	H04R9/00	H04R9/02
H04R9/04	H04R9/06	H04R9/08	H04R9/10	H04R9/12	H04R9/14
H04R9/16	H04R9/18	H04R11/00	H04R11/02	H04R11/04	H04R11/06
H04R11/08	H04R11/10	H04R11/12	H04R11/14	H04R13/00	H04R13/02
H04R15/00	H04R15/02	H04R17/00	H04R17/02	H04R17/04	H04R17/06
H04R17/08	H04R17/10	H04R19/00	H04R19/01	H04R19/02	H04R19/04
H04R19/06	H04R19/08	H04R19/10	H04R21/00	H04R21/02	H04R21/04
H04R23/00	H04R23/02	H04R25/00	H04R25/02	H04R25/04	H04R27/00
H04R27/02	H04R27/04	H04R29/00	H04R31/00	H04S1/00	H04S3/00
H04S3/02	H04S5/00	H04S5/02	H04S7/00	H04W12/00	H04W12/02
H04W12/04	H04W12/06	H04W12/08	H04W12/10	H04W12/12	H04W52/02
H04W72/04	H04W72/06	H04W72/08	H04W72/10	H04W84/00	H04W84/02
H04W84/04	H04W84/06	H04W84/08	H04W84/10	H04W84/12	H04W84/14
H04W84/16	H04W84/18	H04W84/20	H04W84/22		

Annex 2: Definition of the Queries on the Global Patent Index dataset

In order to retrieve the number of patents for each firm, in the Global Patent Index some preliminary operations have been necessary. The name of the firms in the ERM dataset does not respect the same standard of the names of the EPO. Furthermore, the names in the dataset may refer to more than one division or national subsidiary of a firm. So, a correspondence table, using the Orbis software and the *bvd* code (provided in the ERM dataset) of each firm, has been built. At this point, the identification of each firm on the EPO database is clear and unambiguous and the queries for the patents were possible.

The Queries on the Global Patent Index have been conducted by requesting different conditions:

- First, by writing the name the firms belonging to the ERM dataset in the field APP, as applicant of the patent, using the quotes for the names and the bracket for including all the firms.
- For each year, imposing the PRD (priority date) equal to the year desired.
- To request the patent code, imposing the IPC equal to each of the codes in the 4IR report of EPO. Since the GPI query space does not support all the 2870[37] codes together in one query, the collection of the query has been divided into two subsets.
- To obtain the number of the granted patents, the condition ISG ("is granted") has been put equal to "YES".
- The AND connector has been used for all the condition of the queries, so requesting the patents satisfying all the conditions above.

Each of the queries returned the number of patents for the first 50 applicants, so for each subset of queries of each year, were necessary a number of re-runs of the queries until the system returned all the applicant for each subset. In each query, of the first 50 applicants have been excluded using the connector ANDNOT and the field APP, set equal of the applicants to exclude. For each year and each subset of codes, 3 or 4, queries have been necessary. Given the fact that the total number of years is 14 (from 2002 to 2015 plus the initial value of the stock), 96 queries in total have been necessary.

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[37] See Annex 1 for the complete list.

Below is shown an example of one query, including all the firms, for the year 2002 and the first subset of patents (from A01B69/00 to G06N3/00).

APP=(“MINNESOTA MINING MFG” “A B ELEKTRONIK GMBH” “ABB LTD” “AERO VODOCHODY AS” “AGCO CORP” “AKZO NOBEL NV” “ALCAN INT LTD” “ALCATEL LUCENT” “ARCONIC INC” “ALCOA FUJIKURA LTD” “ALSTOM SA” “AMCOR LTD” “AMERICAN POWER CONV CORP” “ANHEUSER BUSCH INBEV SA” “ARA AG” “ARCELORMITTAL S A” “ARLA FOODS AMBA” “AROVIT PETFOOD AS” “ASKO UPO OY” “ASSA OEM AB” “ATLANTA OFFICE PRODUCTS B V” “ATS INC” “AURUBIS AG” “AUTOLIV DEV” “AUTONEUM TECHNOLOGIES AG” “AVERY DENNISON CORP” “AVX CORP” “BASELL POLYOLEFINE GMBH” “BASF AG” “BAUSCH LOMB” “BAXTER INT” “BAYER AG” “BEIERSDORF AG” “BEKAERT SA NV” “BENDICKS NORBERT” “BIRDS EYE HOLDINGS LTD” “BAYERISCHE MOTOREN WERKE AG” “BORYSZEW SPOLKA AKCYJNA ODDZIAL MAFLOW W TYCHACH” “BOSCH GMBH ROBERT” “BOXMARK LEATHER GMBH CO KG F” “BERNWARD LEINEWEBER GMBH CO KG” “BRITISH AMERICAN TOBACCO CO” “BROSE FAHRZEUGTEILE” “BUNDY REFRIGERATION GMBH” “BUNGE OILS INC” “CARGOTEC FINLAND OY” “CARLSBERG AS” “CARRIER CORP” “CATERPILLAR INC” “CELESTICA INC” “CLOETTA AB” “CML INNOVATIVE TECHNOLOGIES” “COLGATE PALMOLIVE CO” “COMMSCOPE INC” “CONTINENTAL AG” “COOPER STANDARD AUTOMOTIVE INC” “CYTEC SURFACE SPECIALTIES SA” “CYTEC SURFACE SPECIALTIES SA” “DANFOSS POWER SOLUTIONS INC” “GERVAIS DANONE SA” “DELL INC” “DELPHI TECH INC” “DELVAUX JOHN MCCONNELL” “DENSO CORP” “DOREL IND INC” “DURA AUTOMOTIVE PLETTENBERG” “E D C SARL” “ELECTROLUX AB” “ELEMENT SIX LTD” “ELOPAK AS” “EMERSON ELECTRIC CO” “ENICS AG” “EPCOS AG” “ERICSSON AB” “ESAB AB” “EXIDE TECHNOLOGIES INC” “FAGOR S COOP” “FAURECIA SIEGES AUTOMOBILE” “FERRING BV” “FERRO CORP” “FIAMM SPA” “FIAT SPA” “FILTRONIC PLC” “FLEXTRONICS AP LLC” “FORD MOTOR CO” “FORMAT TRESORBAU GMBH CO KG” “FRITZ RICHARD GMBH CO KG” “GALLAHER LTD” “GAMBRO LUNDIA AB” “GE HEALTHCARE LTD” “GEIGER GERHARD GMBH CO” “GEN DYNAMICS CORP” “GEN GROWTH PROPERTIES INC” “GEN MOTORS CORP” “FISCHER AG GEORG” “GILLETTE CO” “GIVAUDAN SA” “GOODYEAR TIRE RUBBER” “GLOBAL SAFETY TEXTILES GMBH” “HEINZ CO H J” “HARMAN INT IND” “HEIL TRAILER INTERNATIONAL CO” “HELLA GMBH CO KGAA” “HENKEL AG CO KGAA” “HEWLETT PACKARD CO” “HONDA MOTOR CO LTD” “HONEYWELL INC” “HUSQVARNA AB” “HUTCHINSON” “HYMER AG” “IMP TOBACCO CO LTD” “INDESIT” “WHIRLPOOL EMEA SPA” “INEOS EUROPE LTD” “INT RECTIFIER CORP” “INTEVA PRODUCTS LLC” “INVENTEC CORP” “ISOLA AS” “ITRON INC” “JABIL INC” “JAPAN TOBACCO INC” “JELD WEN INC” “JCB KK” “KION GROUP GMBH” “JOHNSON CONTROLS INC” “HARTWALL K OY AB” “KINNARPS AB” “KME ITALY S P A” “KOENIG BAUER AG” “KONGSBERG AUTOMOTIVE ASA” “KRAFT FOODS HOLDINGS INC” “KROMBERG SCHUBERT GMBH CO” “KTM SPORTMOTORCYCLE AG” “LEAR CORP” “LEONI AG” “LEXMARK INT INC” “LG DISPLAY CO LTD” “LK PRODUCTS OY” “LONZA AG” “MAGNA INT INC” “MAN ENERGY SOLUTIONS SE” “MANN HUMMEL GMBH” “MARS INC” “MARTIN PROFESSIONAL AS” “MELKA AB” “MERCK CO INC” “MERCK KGAA” “MERSEN FRANCE SB SAS” “METHODE ELECTRONICS INC” “METZELER AG” “MFT FR PNEUMATIQUES MICHELIN” “MOHAWK IND INC” “MOLEX INC” “MONDI PACKAGING SOUTH AFRICA PTY LTD” “MORPHO CARDS GMBH” “MTD PRODUCTS INC” “MYLLYKOSKI OYJ” “N W GLOBAL VENDING SPA” “NATUZZI SPA” “NCR CO” “NESTLE SA” “NILFISK AS” “NOBIA AB” “NOKIA OYJ” “NOVARTIS AG” “NOVEM CAR INTERIOR DESIGN GMBH” “NSK LTD” “NXP BV” “TAKEDA PHARMACEUTICAL” “OCE HOLDING B V” “LITE ON SEMICONDUCTOR CORP” “ONTEX BVBA” “ORIFLAME COSMETICS S A” “OSRAM GMBH” “OUTOKUMPU OY” “OUTOKUMPU STAINLESS AB” “PANASONIC CORP” “PARKER HANNIFIN CORP” “PARKER HANNIFIN CORP” “PFIZER” “PHILIP MORRIS INC” “KONINKL PHILIPS NV” “PIAGGIO C SPA” “PLANNJA AB” “POLYTEC GMBH” “PREVENT AUSTRIA GMBH” “PROCTER GAMBLE” “PRYSMIAN SPA” “PSA PEUGEOT CITROEN AUTOMOBILES S A” “QUANTUM CORP” “RECKITT BENCKISER UK LTD” “RELIANCE IND LTD” “REMY INT INC” “RENAULT” “RETTIG ICC BV” “HOFFMANN LA ROCHE” “ROCKWOOD CO” “ROLLS ROYCE PLC” “SAAB AUTOMOBILE” “SABENA” “SABIC INNOVATIVE PLASTICS IP” “SAMSUNG CO LTD” “SANMINA CORP” “SANOFI SA” “SCA HYGIENE PROD AB” “SCHNEIDER ELECTRIC IND SAS” “SCHOEDEL RAINER” “SECOP GMBH” “SICLI” “SIEMENS AG” “SIGMA COATINGS BV” “SITAG AG” “SMITHS INDUSTRIES PLC” “SNA EUROP IND SA” “SOLECTRON CORP” “SOLVAY “ “SONY CORP” “SPECMA AB” “STANLEY BLACK DECKER INC” “STEELCASE INC” “STOCKO CONTACT GMBH CO KG” “STONERIDGE INC” “SULZER AG”

“TAKATA CORP” “TAKEDA RIKEN IND CO LTD” “TARKETT SAS” “TE CONNECTIVITY LTD” “TECHNICOLOR MOTION PICTURE” “TENNECO INC” “TEVA PHARMA” “TE CONNECTIVITY LTD” “THORN LIGHTING LTD” “TEXAS INSTRUMENTS INC” “THYSSENKRUPP ELEVATOR AG” “TOSHIBA CORP” “TRELLEBORG AB” “TRIUMPH CYCLE CO LTD” “TRW AUTOMOTIVE GMBH” “TWR INC” “TYCO ELECTRONICS AMP GMBH” “UNILEVER PLC” “UNOMEDICAL LTD” “VALMET OY” “VARTA AG” “VILLEROY BOCH” “VOLKSWAGEN AG” “VOLVO AB” “WELLA AG” “WHATMAN LTD” “WHIRLPOOL CO” “XEROX CORP” “YAMAHA CORP” “YAZAKI CORP” “YAZAKI WIRING TECHNOLOGIES GMB” “YOPLAIT FRANCE” “ZF SACHS AG” “ZUMTOBEL LIGHTING GMBH”) AND PRD=2002 AND (IPC=A01B69/00 IPC=A01B69/06 IPC=A01B69/08 IPC=A01B69/04 IPC=A01B79/00 IPC=A01C21/00 IPC=A01D34/00 IPC=A01D41/127 IPC=A01D91/00 IPC=A01D91/02 IPC=A01D91/04 IPC=A01G7/04 IPC=A01G25/16 IPC=A01J5/007 IPC=A01J5/01 IPC=A01J5/017 IPC=A01K1/12 IPC=A01K11/00 IPC=A01K15/02 IPC=A01K29/00 IPC=A47G29/14 IPC=A47K5/12 IPC=A47K10/32 IPC=A47L11/40 IPC=A61B1/00 IPC=A61B5/00 IPC=A61B5/145 IPC=A61B6/00 IPC=A61B8/00 IPC=A61B17/00 IPC=A61B34/00 IPC=A61B34/10 IPC=A61B34/20 IPC=A61B34/32 IPC=A61B34/35 IPC=A61B34/37 IPC=A61B90/00 IPC=A61B90/90 IPC=A61B90/92 IPC=A61B90/94 IPC=A61B90/96 IPC=A61B90/98 IPC=A61C7/00 IPC=A61C13/00 IPC=A61F2/30 IPC=A61F5/00 IPC=A61H3/00 IPC=A61H3/02 IPC=A61H3/04 IPC=A61H3/06 IPC=A61H31/00 IPC=A61M16/00 IPC=A61N1/372 IPC=A61N5/10 IPC=A63B24/00 IPC=A63B71/06 IPC=A63F9/24 IPC=A63F13/00 IPC=A63F13/98 IPC=A63F13/219 IPC=A63F13/20 IPC=A63F13/90 IPC=A63F13/40 IPC=A63F13/30 IPC=A63F13/21 IPC=A63F13/211 IPC=A63F13/212 IPC=A63F13/213 IPC=A63F13/214 IPC=A63F13/2145 IPC=A63F13/215 IPC=A63F13/216 IPC=A63F13/217 IPC=A63F13/218 IPC=A63F13/22 IPC=A63F13/23 IPC=A63F13/235 IPC=A63F13/24 IPC=A63F13/245 IPC=A63F13/25 IPC=A63F13/26 IPC=A63F13/27 IPC=A63F13/28 IPC=A63F13/285 IPC=A63F13/31 IPC=A63F13/32 IPC=A63F13/323 IPC=A63F13/327 IPC=A63F13/33 IPC=A63F13/332 IPC=A63F13/335 IPC=A63F13/338 IPC=A63F13/34 IPC=A63F13/35 IPC=A63F13/352 IPC=A63F13/355 IPC=A63F13/358 IPC=A63F13/42 IPC=A63F13/422 IPC=A63F13/424 IPC=A63F13/426 IPC=A63F13/428 IPC=A63F13/44 IPC=A63F13/45 IPC=A63F13/46 IPC=A63F13/47 IPC=A63F13/48 IPC=A63F13/49 IPC=A63F13/493 IPC=A63F13/497 IPC=A63F13/50 IPC=A63F13/52 IPC=A63F13/525 IPC=A63F13/5252 IPC=A63F13/5255 IPC=A63F13/5258 IPC=A63F13/53 IPC=A63F13/533 IPC=A63F13/537 IPC=A63F13/5372 IPC=A63F13/5375 IPC=A63F13/5378 IPC=A63F13/54 IPC=A63F13/55 IPC=A63F13/56 IPC=A63F13/57 IPC=A63F13/573 IPC=A63F13/577 IPC=A63F13/58 IPC=A63F13/60 IPC=A63F13/61 IPC=A63F13/63 IPC=A63F13/65 IPC=A63F13/655 IPC=A63F13/67 IPC=A63F13/69 IPC=A63F13/70 IPC=A63F13/71 IPC=A63F13/73 IPC=A63F13/75 IPC=A63F13/77 IPC=A63F13/79 IPC=A63F13/792 IPC=A63F13/795 IPC=A63F13/798 IPC=A63F13/80 IPC=A63F13/803 IPC=A63F13/807 IPC=A63F13/812 IPC=A63F13/814 IPC=A63F13/816 IPC=A63F13/818 IPC=A63F13/822 IPC=A63F13/825 IPC=A63F13/828 IPC=A63F13/833 IPC=A63F13/837 IPC=A63F13/843 IPC=A63F13/847 IPC=A63F13/85 IPC=A63F13/86 IPC=A63F13/87 IPC=A63F13/88 IPC=A63F13/92 IPC=A63F13/95 IPC=B01L3/00 IPC=B05B12/00 IPC=B05B12/02 IPC=B05B12/04 IPC=B05B12/06 IPC=B05B12/08 IPC=B05B12/10 IPC=B05B12/12 IPC=B05B12/14 IPC=B05C11/10 IPC=B05C11/105 IPC=B60C23/04 IPC=B60C25/05 IPC=B60D1/01 IPC=B60D1/02 IPC=B60D1/04 IPC=B60D1/06 IPC=B60D1/07 IPC=B60D1/24 IPC=B60D1/26 IPC=B60D1/28 IPC=B60D1/30 IPC=B60D1/32 IPC=B60D1/34 IPC=B60D1/36 IPC=B60D1/38 IPC=B60D1/40 IPC=B60D1/42 IPC=B60D1/44 IPC=B60D1/46 IPC=B60D1/48 IPC=B60D1/50 IPC=B60D1/52 IPC=B60D1/54 IPC=B60D1/56 IPC=B60H1/00 IPC=B60K28/00 IPC=B60K28/02 IPC=B60K28/04 IPC=B60K28/06 IPC=B60K28/08 IPC=B60K28/10 IPC=B60K28/12 IPC=B60K28/14 IPC=B60K28/16 IPC=B60K31/00 IPC=B60K31/02 IPC=B60K31/04 IPC=B60K31/06 IPC=B60K31/08 IPC=B60K31/10 IPC=B60K31/12 IPC=B60K31/14 IPC=B60K31/16 IPC=B60K31/18 IPC=B60K35/00 IPC=B60K37/06 IPC=B60L11/18 IPC=B60N2/00 IPC=B60N2/02 IPC=B60N2/28 IPC=B60P1/00 IPC=B60P1/02 IPC=B60P1/04 IPC=B60P1/06 IPC=B60P1/08 IPC=B60P1/10 IPC=B60P1/12 IPC=B60P1/14 IPC=B60P1/16 IPC=B60P1/18 IPC=B60P1/20 IPC=B60P1/22 IPC=B60P1/24 IPC=B60P1/26 IPC=B60P1/267 IPC=B60P1/273 IPC=B60P1/28 IPC=B60P1/30 IPC=B60P1/32 IPC=B60P1/34 IPC=B60P1/36 IPC=B60P1/38 IPC=B60P1/40 IPC=B60P1/42 IPC=B60P1/43 IPC=B60P1/44 IPC=B60P1/48 IPC=B60P1/50 IPC=B60P1/52 IPC=B60P1/54 IPC=B60P1/56 IPC=B60P1/58 IPC=B60P1/60 IPC=B60P1/62 IPC=B60P1/64 IPC=B60P3/00 IPC=B60P3/025 IPC=B60P3/03 IPC=B60P3/035 IPC=B60P3/04 IPC=B60P3/05 IPC=B60P3/055 IPC=B60P3/06 IPC=B60P3/07 IPC=B60P3/071 IPC=B60P3/073 IPC=B60P3/075 IPC=B60P3/077 IPC=B60P3/079 IPC=B60P3/08 IPC=B60P3/10 IPC=B60P3/11 IPC=B60P3/12 IPC=B60P3/14 IPC=B60P3/16 IPC=B60P3/18 IPC=B60P3/20 IPC=B60P3/22 IPC=B60P3/24 IPC=B60P3/28 IPC=B60P3/30 IPC=B60P3/32 IPC=B60P3/34 IPC=B60P3/36 IPC=B60P3/38 IPC=B60P3/39

IPC=B60P3/40 IPC=B60P3/41 IPC=B60P3/42 IPC=B60P7/00 IPC=B60P7/02 IPC=B60P7/04 IPC=B60P7/06
IPC=B60P7/08 IPC=B60P7/10 IPC=B60P7/12 IPC=B60P7/13 IPC=B60P7/135 IPC=B60P7/14 IPC=B60P7/15
IPC=B60P7/16 IPC=B60P7/18 IPC=B60P9/00 IPC=B60Q1/08 IPC=B60Q1/10 IPC=B60Q1/105
IPC=B60Q1/11 IPC=B60Q1/115 IPC=B60Q1/12 IPC=B60Q1/124 IPC=B60Q1/14 IPC=B60Q1/34
IPC=B60Q1/40 IPC=B60Q1/42 IPC=B60Q1/44 IPC=B60Q1/52 IPC=B60Q3/00 IPC=B60Q3/10 IPC=B60Q3/12
IPC=B60Q3/14 IPC=B60Q3/16 IPC=B60Q3/18 IPC=B60Q3/20 IPC=B60Q3/208 IPC=B60Q3/217
IPC=B60Q3/225 IPC=B60Q3/233 IPC=B60Q3/242 IPC=B60Q3/252 IPC=B60Q3/258 IPC=B60Q3/267
IPC=B60Q3/275 IPC=B60Q3/283 IPC=B60Q3/292 IPC=B60Q3/30 IPC=B60Q3/35 IPC=B60Q3/40
IPC=B60Q3/41 IPC=B60Q3/43 IPC=B60Q3/44 IPC=B60Q3/46 IPC=B60Q3/47 IPC=B60Q3/49 IPC=B60Q3/50
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IPC=B60Q3/62 IPC=B60Q3/64 IPC=B60Q3/66 IPC=B60Q3/68 IPC=B60Q3/70 IPC=B60Q3/72 IPC=B60Q3/74
IPC=B60Q3/76 IPC=B60Q3/78 IPC=B60Q3/80 IPC=B60Q3/82 IPC=B60Q5/00 IPC=B60Q9/00
IPC=B60R25/04 IPC=B60R25/042 IPC=B60R25/043 IPC=B60R25/044 IPC=B60R25/045 IPC=B60R25/06
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IPC=B60S1/08 IPC=B60S1/48 IPC=B60S1/56 IPC=B60S1/58 IPC=B60S1/60 IPC=B60S3/00 IPC=B60S3/04
IPC=B60S3/06 IPC=B60S5/02 IPC=B60S5/06 IPC=B60T7/12 IPC=B60T7/14 IPC=B60T7/16 IPC=B60T7/18
IPC=B60T7/20 IPC=B60T7/22 IPC=B60T8/1755 IPC=B60T13/66 IPC=B60T13/68 IPC=B60T13/70
IPC=B60T13/72 IPC=B60T13/74 IPC=B60T17/18 IPC=B60T17/20 IPC=B60T17/22 IPC=B60W10/00
IPC=B60W30/00 IPC=B60W30/02 IPC=B60W30/04 IPC=B60W30/045 IPC=B60W30/06 IPC=B60W30/08
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IPC=B60W30/186 IPC=B60W30/188 IPC=B60W30/19 IPC=B60W30/192 IPC=B60W30/194 IPC=B60W30/20
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IPC=B60W40/072 IPC=B60W40/076 IPC=B60W40/08 IPC=B60W40/09 IPC=B60W40/10 IPC=B60W40/101
IPC=B60W40/103 IPC=B60W40/105 IPC=B60W40/107 IPC=B60W40/109 IPC=B60W40/11 IPC=B60W40/112
IPC=B60W40/114 IPC=B60W40/12 IPC=B60W40/13 IPC=B60W50/00 IPC=B60W50/02 IPC=B60W50/023
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IPC=B61L3/02 IPC=B61L3/04 IPC=B61L3/06 IPC=B61L3/08 IPC=B61L3/10 IPC=B61L3/12 IPC=B61L3/14
IPC=B61L3/16 IPC=B61L3/18 IPC=B61L3/20 IPC=B61L3/22 IPC=B61L3/24 IPC=B61L15/00 IPC=B61L15/02
IPC=B61L23/00 IPC=B61L23/02 IPC=B61L23/04 IPC=B61L23/06 IPC=B61L23/08 IPC=B61L23/10
IPC=B61L23/12 IPC=B61L23/14 IPC=B61L23/16 IPC=B61L23/18 IPC=B61L23/20 IPC=B61L23/22
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IPC=B64F1/36 IPC=B64F5/10 IPC=B64F5/40 IPC=B64F5/45 IPC=B64F5/60 IPC=B65B57/00 IPC=B65B57/02
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IPC=D06M11/20 IPC=D06M11/22 IPC=D06M11/24 IPC=D06M11/26 IPC=D06M11/28 IPC=D06M11/30
IPC=D06M11/32 IPC=D06M11/34 IPC=D06M11/36 IPC=D06M11/38 IPC=D06M11/40 IPC=D06M11/42
IPC=D06M11/44 IPC=D06M11/45 IPC=D06M11/46 IPC=D06M11/47 IPC=D06M11/48 IPC=D06M11/49
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IPC=D06M11/68 IPC=D06M11/69 IPC=D06M11/70 IPC=D06M11/71 IPC=D06M11/72 IPC=D06M11/73
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IPC=G06F12/00 IPC=G06F12/02 IPC=G06F12/04 IPC=G06F12/06 IPC=G06F12/08 IPC=G06F12/0802 IPC=G06F12/0804 IPC=G06F12/0806 IPC=G06F12/0808 IPC=G06F12/0811 IPC=G06F12/0813 IPC=G06F12/0815 IPC=G06F12/0817 IPC=G06F12/0831 IPC=G06F12/0837 IPC=G06F12/084 IPC=G06F12/0842 IPC=G06F12/0844 IPC=G06F12/0846 IPC=G06F12/0853 IPC=G06F12/0855 IPC=G06F12/0862 IPC=G06F12/0864 IPC=G06F12/0866 IPC=G06F12/0868 IPC=G06F12/0871 IPC=G06F12/0873 IPC=G06F12/0875 IPC=G06F12/0877 IPC=G06F12/0879 IPC=G06F12/0882 IPC=G06F12/0884 IPC=G06F12/0886 IPC=G06F12/0888 IPC=G06F12/0891 IPC=G06F12/0893 IPC=G06F12/0895 IPC=G06F12/0897 IPC=G06F12/10 IPC=G06F12/1009 IPC=G06F12/1018 IPC=G06F12/1027 IPC=G06F12/1036 IPC=G06F12/1045 IPC=G06F12/1072 IPC=G06F12/1081 IPC=G06F12/109 IPC=G06F12/12 IPC=G06F12/121 IPC=G06F12/122 IPC=G06F12/123 IPC=G06F12/126 IPC=G06F12/127 IPC=G06F12/128 IPC=G06F12/14 IPC=G06F17/00 IPC=G06F17/10 IPC=G06F17/11 IPC=G06F17/12 IPC=G06F17/13 IPC=G06F17/14 IPC=G06F17/15 IPC=G06F17/16 IPC=G06F17/17 IPC=G06F17/18 IPC=G06F17/20 IPC=G06F17/21 IPC=G06F17/22 IPC=G06F17/24 IPC=G06F17/25 IPC=G06F17/26 IPC=G06F17/27 IPC=G06F17/28 IPC=G06F17/30 IPC=G06F17/40 IPC=G06F17/50 IPC=G06F19/10 IPC=G06F19/12 IPC=G06F19/14 IPC=G06F19/16 IPC=G06F19/18 IPC=G06F19/20 IPC=G06F19/22 IPC=G06F19/24 IPC=G06F19/26 IPC=G06F19/28 IPC=G06F19/00 IPC=G06F21/00 IPC=G06F21/10 IPC=G06F21/12 IPC=G06F21/14 IPC=G06F21/16 IPC=G06F21/30 IPC=G06F21/31 IPC=G06F21/32 IPC=G06F21/33 IPC=G06F21/34 IPC=G06F21/35 IPC=G06F21/36 IPC=G06F21/40 IPC=G06F21/41 IPC=G06F21/42 IPC=G06F21/43 IPC=G06F21/44 IPC=G06F21/45 IPC=G06F21/46 IPC=G06F21/50 IPC=G06F21/51 IPC=G06F21/52 IPC=G06F21/53 IPC=G06F21/54 IPC=G06F21/55 IPC=G06F21/56 IPC=G06F21/57 IPC=G06F21/60 IPC=G06F21/62 IPC=G06F21/64 IPC=G06F21/70 IPC=G06F21/71 IPC=G06F21/72 IPC=G06F21/73 IPC=G06F21/74 IPC=G06F21/75 IPC=G06F21/76 IPC=G06F21/77 IPC=G06F21/78 IPC=G06F21/79 IPC=G06F21/80 IPC=G06F21/81 IPC=G06F21/82 IPC=G06F21/83 IPC=G06F21/84 IPC=G06F21/85 IPC=G06F21/86 IPC=G06F21/87 IPC=G06F21/88 IPC=G06K1/00 IPC=G06K1/02 IPC=G06K1/04 IPC=G06K1/05 IPC=G06K1/06 IPC=G06K1/08 IPC=G06K1/10 IPC=G06K1/12 IPC=G06K1/14 IPC=G06K1/16 IPC=G06K1/18 IPC=G06K1/20 IPC=G06K1/22 IPC=G06K3/00 IPC=G06K3/02 IPC=G06K5/00 IPC=G06K5/02 IPC=G06K5/04 IPC=G06K7/00 IPC=G06K7/01 IPC=G06K7/015 IPC=G06K7/016 IPC=G06K7/02 IPC=G06K7/04 IPC=G06K7/06 IPC=G06K7/08 IPC=G06K7/10 IPC=G06K7/12 IPC=G06K7/14 IPC=G06K9/00 IPC=G06K9/03 IPC=G06K9/18 IPC=G06K9/20 IPC=G06K9/22 IPC=G06K9/24 IPC=G06K9/26 IPC=G06K9/28 IPC=G06K9/30 IPC=G06K9/32 IPC=G06K9/34 IPC=G06K9/36 IPC=G06K9/38 IPC=G06K9/40 IPC=G06K9/42 IPC=G06K9/44 IPC=G06K9/46 IPC=G06K9/48 IPC=G06K9/50 IPC=G06K9/52 IPC=G06K9/54 IPC=G06K9/56 IPC=G06K9/58 IPC=G06K9/60 IPC=G06K9/62 IPC=G06K9/64 IPC=G06K9/66 IPC=G06K9/68 IPC=G06K9/70 IPC=G06K9/72 IPC=G06K9/74 IPC=G06K9/76 IPC=G06K9/78 IPC=G06K9/80 IPC=G06K9/82 IPC=G06K11/00 IPC=G06K11/02 IPC=G06K11/04 IPC=G06K11/06 IPC=G06K13/00 IPC=G06K13/02 IPC=G06K13/04 IPC=G06K13/05 IPC=G06K13/06 IPC=G06K13/063 IPC=G06K13/067 IPC=G06K13/07 IPC=G06K13/073 IPC=G06K13/077 IPC=G06K13/08 IPC=G06K13/10 IPC=G06K13/103 IPC=G06K13/107 IPC=G06K13/12 IPC=G06K13/14 IPC=G06K13/16 IPC=G06K13/18 IPC=G06K13/20 IPC=G06K13/22 IPC=G06K13/24 IPC=G06K13/26 IPC=G06K13/28 IPC=G06K13/30 IPC=G06K15/00 IPC=G06K15/02 IPC=G06K15/04 IPC=G06K15/06 IPC=G06K15/07 IPC=G06K15/08 IPC=G06K15/10 IPC=G06K15/12 IPC=G06K15/14 IPC=G06K15/16 IPC=G06K15/22 IPC=G06K17/00 IPC=G06K19/00 IPC=G06K19/02 IPC=G06K19/04 IPC=G06K19/06 IPC=G06K19/063 IPC=G06K19/067 IPC=G06K19/07 IPC=G06K19/073 IPC=G06K19/077 IPC=G06K19/08 IPC=G06K19/10 IPC=G06K19/12 IPC=G06K19/14 IPC=G06K19/16 IPC=G06K19/18 IPC=G06K21/00 IPC=G06K21/02 IPC=G06K21/04 IPC=G06K21/06 IPC=G06K21/08 IPC=G06N3/00) AND ISG=YES

Annex 3: Results of the analysis of the interaction for the variables

First specification: Differences between first host and home country

Interaction considering the number of patents

Interaction between Cost seeking and number of patents	Sample				EU-HQ			
	Coef.	R. Std. Err.	z	P>z	Coef.	R. Std. Err.	z	P>z
Offshoring Market Driver	1.8522	0.3342	5.54	**0**	-0.0338	1.0942	-0.03	0.975
Offshoring Asset Driver	0.3279	0.2420	1.35	0.175	0.2725	0.2601	1.05	0.295
Offshoring Cost Driver	-0.4817	0.2822	-1.71	**0.088**	-0.3638	0.3021	-1.2	0.229
Patents in FIR	0.0234	0.1784	0.13	0.895	-0.1510	0.2360	-0.64	0.522
Cost → Patents in FIR	***-0.0543***	***0.1228***	***-0.44***	***0.658***	***0.7599***	***0.3229***	***2.35***	***0.019***
Offshoring Productivity Driver	-0.0005	0.2659	0	0.998	-0.1348	0.2345	-0.57	0.565
Crisis 08-11	0.8812	0.5210	1.69	**0.091**	1.3093	0.5712	2.29	**0.022**
Crisis 12-15	0.9456	0.6273	1.51	0.132	1.1961	0.7170	1.67	**0.095**
Size Total Assets	0.2739	0.1354	2.02	**0.043**	0.2003	0.1454	1.38	0.168
Host1, East-EU	0.9477	0.7428	1.28	0.202	0.0363	0.9540	0.04	0.97
Host2/Home, East-EU	-3.8756	0.7642	-5.07	**0**	-3.7266	0.7158	-5.21	**0**
Euro Currency	-0.4516	0.5252	-0.86	0.39	-0.5646	0.6647	-0.85	0.396
High-Tech Control	0.6534	0.4775	1.37	0.171	0.5843	0.5335	1.1	0.273
Industry 4.0	-0.0627	0.8557	-0.07	0.942	-0.5296	0.8555	-0.62	0.536
Interaction between Productivity and number of patents	Sample				EU-HQ			
	Coef.	R. Std. Err.	z	P>z	Coef.	R. Std. Err.	z	P>z
Offshoring Market Driver	1.8577	0.3334	5.57	**0**	-0.0886	1.0901	-0.08	0.935
Offshoring Asset Driver	0.3310	0.2406	1.38	0.169	0.2731	0.2597	1.05	0.293
Offshoring Cost Driver	-0.0106	0.2616	-0.04	0.968	-0.1383	0.2319	-0.6	0.551
Offshoring Productivity Driver	-0.4805	0.2820	-1.7	**0.088**	-0.5011	0.3263	-1.54	0.125
Patents in FIR	-0.0287	0.1657	-0.17	0.863	-0.0838	0.2104	-0.4	0.69
Productivity → Patents in FIR	***-0.0404***	***0.2001***	***-0.2***	***0.84***	***-0.0840***	***0.2383***	***-0.35***	***0.724***
Crisis 08-11	0.8911	0.5138	1.73	**0.083**	1.2301	0.5539	2.22	**0.026**
Crisis 12-15	0.9559	0.6190	1.54	0.123	1.1650	0.7117	1.64	0.102
Size Total Assets	0.2727	0.1356	2.01	**0.044**	0.2075	0.1443	1.44	0.15
Host1, East-EU	0.9522	0.7475	1.27	0.203	-0.0217	0.9479	-0.02	0.982
Host2/Home, East-EU	-3.8671	0.7647	-5.06	**0**	-3.7271	0.7130	-5.23	**0**
Euro Currency	-0.4533	0.5288	-0.86	0.391	-0.5646	0.6618	-0.85	0.394
High-Tech Control	0.6562	0.4764	1.38	0.168	0.5767	0.5356	1.08	0.282
Industry 4.0	-0.0561	0.8557	-0.07	0.948	-0.4830	0.8435	-0.57	0.567
Interaction between Assets seeking and number of patents	Sample				EU-HQ			
	Coef.	R. Std. Err.	z	P>z	Coef.	R. Std. Err.	z	P>z
Offshoring Market Driver	1.7783	0.3253	5.47	**0**	-0.1292	1.0896	-0.12	0.906
Offshoring Asset Driver	0.4917	0.2360	2.08	**0.037**	0.3315	0.2639	1.26	0.209
Patents in FIR	0.1060	0.2514	0.42	0.673	-0.0120	0.2086	-0.06	0.954
Asset → Patents in FIR	***0.8274***	***0.4280***	***1.93***	***0.053***	***0.3006***	***0.3457***	***0.87***	***0.385***
Offshoring Cost Driver	-0.4467	0.2953	-1.51	0.13	-0.4982	0.3251	-1.53	0.125
Offshoring Productivity Driver	-0.0196	0.2744	-0.07	0.943	-0.1289	0.2303	-0.56	0.576
Crisis 08-11	0.9112	0.5150	1.77	**0.077**	1.2326	0.5507	2.24	**0.025**
Crisis 12-15	0.9575	0.6340	1.51	0.131	1.1488	0.7110	1.62	0.106
Size Total Assets	0.2590	0.1335	1.94	**0.052**	0.2040	0.1457	1.4	0.162
Host1, East-EU	1.0314	0.7571	1.36	0.173	0.0334	0.9441	0.04	0.972
Host2/Home, East-EU	-3.8650	0.7822	-4.94	**0**	-3.7002	0.7099	-5.21	**0**
Euro Currency	-0.3282	0.5416	-0.61	0.545	-0.4980	0.6628	-0.75	0.452
High-Tech Control	0.6535	0.4782	1.37	0.172	0.5689	0.5333	1.07	0.286
Industry 4.0	-0.2507	0.8888	-0.28	0.778	-0.5834	0.8572	-0.68	0.496

Table 0.1 - Results of the interaction logit models for Patents in FIR technologies. First Host vs Home Country

Interaction considering Industry 4.0

Interaction between Cost Seeking and Industry 4.0	Sample				EU-HQ			
	Coef.	R. Std. Err.	z	P>z	Coef.	R. Std. Err.	z	P>z
Offshoring Market Driver	1.8828	0.3416	5.51	**0**	-0.0531	1.1207	-0.05	0.962
Offshoring Asset Driver	0.3272	0.2423	1.35	0.177	0.2668	0.2628	1.02	0.31
Offshoring Cost Driver	-0.4716	0.2768	-1.7	**0.088**	-0.4779	0.3229	-1.48	0.139
Industry 4.0	0.6520	1.0591	0.62	0.538	0.3612	1.0950	0.33	0.742
Industry 4.0→Offshoring Cost Driver	***-5.8006***	***2.6278***	***-2.21***	***0.027***	***-6.4271***	***2.8062***	***-2.29***	***0.022***
Offshoring Productivity Driver	0.0044	0.2641	0.02	0.987	-0.1091	0.2275	-0.48	0.632
Crisis 08-11	0.8617	0.5128	1.68	**0.093**	1.1742	0.5474	2.15	**0.032**
Crisis 12-15	0.9468	0.6209	1.52	0.127	1.1441	0.7162	1.6	0.11
Size Total Assets	0.2897	0.1370	2.11	**0.034**	0.2295	0.1460	1.57	0.116
Host1, East-EU	0.8875	0.7448	1.19	0.233	-0.0900	0.9509	-0.09	0.925
Host2/Home, East-EU	-3.8767	0.7638	-5.08	**0**	-3.7430	0.7008	-5.34	**0**
Euro Currency	-0.5267	0.5326	-0.99	0.323	-0.6356	0.6534	-0.97	0.331
High-Tech Control	0.5507	0.4868	1.13	0.258	0.4567	0.5490	0.83	0.405
Patents in FIR	0.0817	0.1608	0.51	0.611	0.0652	0.1660	0.39	0.695

Interaction between Productivity and Industry 4.0	Sample				EU-HQ			
	Coef.	R. Std. Err.	z	P>z	Coef.	R. Std. Err.	z	P>z
Market (Home Country)	1.8564	0.3332	5.57	**0**	-0.0889	1.0913	-0.08	0.935
Offshoring Asset Driver	0.3198	0.2444	1.31	0.191	0.2663	0.2626	1.01	0.311
Offshoring Cost Driver	-0.4804	0.2809	-1.71	**0.087**	-0.5008	0.3256	-1.54	0.124
Offshoring Productivity Driver	-0.0011	0.2656	0	0.997	-0.1179	0.2272	-0.52	0.604
Industry 4.0	-0.6893	1.6759	-0.41	0.681	-0.8404	1.6923	-0.5	0.619
Industry 4.0 → Productivity	***-1.4811***	***3.6762***	***-0.4***	***0.687***	***-0.8329***	***3.5361***	***-0.24***	***0.814***
Crisis 08-11	0.8860	0.5136	1.73	**0.084**	1.2227	0.5528	2.21	**0.027**
Crisis 12-15	0.9561	0.6195	1.54	0.123	1.1631	0.7117	1.63	0.102
Size Total Assets	0.2693	0.1359	1.98	**0.047**	0.2068	0.1437	1.44	0.15
Host1, East-EU	0.9534	0.7435	1.28	0.2	-0.0064	0.9362	-0.01	0.995
Host2/Home, East-EU	-3.8679	0.7648	-5.06	**0**	-3.7340	0.7095	-5.26	**0**
Euro Currency	-0.4486	0.5270	-0.85	0.395	-0.5518	0.6506	-0.85	0.396
High-Tech Control	0.6507	0.4772	1.36	0.173	0.5748	0.5366	1.07	0.284
Patents in FIR	-0.0045	0.1772	-0.03	0.98	-0.0129	0.1718	-0.08	0.94

Interaction between Asset Seeking and Industry 4.0	Sample				EU-HQ			
	Coef.	R. Std. Err.	z	P>z	Coef.	R. Std. Err.	z	P>z
Offshoring Market Driver	1.8471	0.3317	5.57	**0**	-0.1134	1.0977	-0.1	0.918
Offshoring Asset Driver	0.3001	0.2493	1.2	0.229	0.2469	0.2666	0.93	0.354
Industry 4.0	0.0369	0.9511	0.04	0.969	-0.3746	0.9248	-0.41	0.685
Industry 4.0 → Asset	***0.6794***	***0.9375***	***0.72***	***0.469***	***0.5593***	***0.9227***	***0.61***	***0.544***
Offshoring Cost Driver	-0.4744	0.2810	-1.69	**0.091**	-0.4955	0.3245	-1.53	0.127
Offshoring Productivity Driver	-0.0055	0.2680	-0.02	0.984	-0.1221	0.2288	-0.53	0.594
Crisis 08-11	0.8767	0.5118	1.71	**0.087**	1.2091	0.5499	2.2	**0.028**
Crisis 12-15	0.9469	0.6210	1.52	0.127	1.1554	0.7125	1.62	0.105
Size Total Assets	0.2638	0.1351	1.95	**0.051**	0.2020	0.1429	1.41	0.157
Host1, East-EU	0.9390	0.7439	1.26	0.207	-0.0238	0.9368	-0.03	0.98
Host2/Home, East-EU	-3.8468	0.7638	-5.04	**0**	-3.7077	0.7086	-5.23	**0**
Euro Currency	-0.4315	0.5305	-0.81	0.416	-0.5385	0.6527	-0.83	0.409
High-Tech Control	0.6332	0.4803	1.32	0.187	0.5567	0.5404	1.03	0.303
Patents in FIR	-0.0378	0.2112	-0.18	0.858	-0.0352	0.1903	-0.18	0.853

Table 0.2 - Results of the interaction logit models for Industry4.0.
First Host vs Home Country

Second specification: differences between second host/home country and first host country

Interaction considering the number of patents

Interaction between Cost Seeking and number of patents	Sample				EU-HQ			
	Coef.	R. Std. Err.	z	P>z	Coef.	R. Std. Err.	z	P>z
Relocation Market Driver	0.3061	0.2055	1.49	0.136	0.3615	0.2393	1.51	0.131
Relocation Asset Driver	0.4183	0.2054	2.04	**0.042**	0.2242	0.2239	1	0.317
Relocation Cost Driver	0.0138	0.2851	0.05	0.961	-0.3409	0.2620	-1.3	0.193
Patents in FIR	-0.5341	0.3845	-1.39	0.165	-0.3227	0.2655	-1.22	0.224
Cost→ Patents in FIR	***1.6851***	***1.0802***	***1.56***	***0.119***	***0.6931***	***0.3714***	***1.87***	***0.062***
Relocation Productivity Driver	0.1116	0.2315	0.48	0.63	0.2442	0.2747	0.89	0.374
Crisis 08-11	0.5370	0.4149	1.29	0.196	1.1474	0.5321	2.16	**0.031**
Crisis 12-15	0.5082	0.5043	1.01	0.314	1.0348	0.6112	1.69	**0.09**
Size Total Asset	0.0155	0.1355	0.11	0.909	0.2046	0.1629	1.26	0.209
Host1, East-EU	-0.3931	0.6934	-0.57	0.571	-1.0451	0.9548	-1.09	0.274
Host2/Home, East-EU	-2.9547	0.8527	-3.47	**0.001**	-3.1520	0.9610	-3.28	**0.001**
Euro Currency	-0.5384	0.4757	-1.13	0.258	-0.8203	0.6874	-1.19	0.233
High Tech Control	0.0646	0.3932	0.16	0.87	0.3719	0.5064	0.73	0.463
Industry 4.0	-0.3273	0.7549	-0.43	0.665	-0.7061	0.8734	-0.81	0.419

Interaction between Productivity and number of patents	Sample				EU-HQ			
	Coef.	R. Std. Err.	z	P>z	Coef.	R. Std. Err.	z	P>z
Relocation Market Driver	0.3427	0.2071	1.65	**0.098**	0.3949	0.2381	1.66	**0.097**
Relocation Asset Driver	0.4684	0.2061	2.27	**0.023**	0.2554	0.2229	1.15	0.252
Relocation Cost Driver	-0.2090	0.2182	-0.96	0.338	-0.4534	0.2554	-1.78	**0.076**
Relocation Productivity Driver	0.1370	0.2195	0.62	0.533	0.3023	0.2743	1.1	0.271
Patents in FIR	-0.0976	0.1933	-0.5	0.614	-0.1275	0.1507	-0.85	0.398
Productivity → Patents in FIR	***0.0618***	***0.1907***	***0.32***	***0.746***	***0.1238***	***0.1575***	***0.79***	***0.432***
Crisis 08-11	0.5084	0.4190	1.21	0.225	1.1228	0.5326	2.11	**0.035**
Crisis 12-15	0.5062	0.5014	1.01	0.313	1.0182	0.6078	1.68	**0.094**
Size Total Asset	0.0063	0.1361	0.05	0.963	0.1730	0.1491	1.16	0.246
Host1, East-EU	-0.5989	0.6908	-0.87	0.386	-1.1728	0.9533	-1.23	0.219
Host2/Home, East-EU	-2.7017	0.7824	-3.45	**0.001**	-3.0618	0.9532	-3.21	**0.001**
Euro Currency	-0.5008	0.4726	-1.06	0.289	-0.7555	0.6859	-1.1	0.271
High Tech Control	0.0074	0.3926	0.02	0.985	0.3635	0.5057	0.72	0.472
Industry 4.0	-0.3837	0.7476	-0.51	0.608	-0.8236	0.8554	-0.96	0.336

Interaction between Asset Seeking and number of patents	Sample				EU-HQ			
	Coef.	R. Std. Err.	z	P>z	Coef.	R. Std. Err.	z	P>z
Relocation Market Driver	0.3530	0.2082	1.7	**0.09**	0.3992	0.2393	1.67	**0.095**
Relocation Asset Driver	0.4447	0.2115	2.1	**0.035**	0.2589	0.2238	1.16	0.247
Patents in FIR	-0.0585	0.1855	-0.32	0.753	-0.0334	0.1601	-0.21	0.835
Asset → Patents in FIR	***-0.2162***	***0.2104***	***-1.03***	***0.304***	***-0.0152***	***0.1959***	***-0.08***	***0.938***
Relocation Cost Driver	-0.1865	0.2145	-0.87	0.385	-0.4212	0.2424	-1.74	**0.082**
Relocation Productivity Driver	0.1411	0.2218	0.64	0.525	0.2862	0.2804	1.02	0.307
Crisis 08-11	0.4891	0.4189	1.17	0.243	1.1341	0.5330	2.13	**0.033**
Crisis 12-15	0.4849	0.5014	0.97	0.334	1.0202	0.6102	1.67	**0.095**
Size Total Asset	-0.0076	0.1431	-0.05	0.958	0.1732	0.1453	1.19	0.233
Host1, East-EU	-0.5883	0.6985	-0.84	0.4	-1.1827	0.9545	-1.24	0.215
Host2/Home, East-EU	-2.6903	0.7879	-3.41	**0.001**	-3.0336	0.9492	-3.2	**0.001**
Euro Currency	-0.4195	0.4813	-0.87	0.383	-0.7310	0.7033	-1.04	0.299
High Tech Control	0.0246	0.3933	0.06	0.95	0.3549	0.5051	0.7	0.482
Industry 4.0	-0.5995	0.7629	-0.79	0.432	-0.8555	0.8782	-0.97	0.33

Table 0.3 - Results of the interaction logit models for Patents in FIR technologies.
Second host/home vs First host country

Interaction considering Industry 4.0

Interaction between Cost Seeking and Industry 4.0	Sample				EU-HQ			
	Coef.	R. Std. Err.	z	P>z	Coef.	R. Std. Err.	z	P>z
Relocation Market Driver	0.3398	0.2091	1.63	0.104	0.3351	0.2457	1.36	0.173
Relocation Asset Driver	0.4603	0.2097	2.19	**0.028**	0.3103	0.2260	1.37	0.17
Relocation Cost Driver	-0.2048	0.2149	-0.95	0.34	-0.3590	0.2386	-1.5	0.132
Industry 4.0	-0.5700	0.7651	-0.75	0.456	806.7791	66.0836	12.21	**0**
Industry 4.0 → Cost	***0.9090***	***2.1838***	***0.42***	***0.677***	***-3178.3670***	***257.5631***	***-12.34***	***0***
Relocation Productivity Driver	0.1307	0.2217	0.59	0.556	0.3076	0.2911	1.06	0.291
Crisis 08-11	0.5058	0.4189	1.21	0.227	1.1815	0.5296	2.23	**0.026**
Crisis 12-15	0.5089	0.5006	1.02	0.309	0.7563	0.6178	1.22	0.221
Size Total Asset	0.0043	0.1368	0.03	0.975	0.1877	0.1441	1.3	0.193
Host1, East-EU	-0.5836	0.6947	-0.84	0.401	-1.3122	0.9854	-1.33	0.183
Host2/Home, East-EU	-2.7136	0.7886	-3.44	**0.001**	-2.8318	0.9276	-3.05	**0.002**
Euro Currency	-0.4934	0.4725	-1.04	0.296	-0.7158	0.6999	-1.02	0.306
High Tech Control	0.0088	0.3927	0.02	0.982	0.0150	0.5167	0.03	0.977
Patents in FIR	-0.0644	0.1859	-0.35	0.729	-0.1018	0.2219	-0.46	0.646

Interaction between Productivity and Industry 4.0	Sample				EU-HQ			
	Coef.	R. Std. Err.	z	P>z	Coef.	R. Std. Err.	z	P>z
Relocation Market Driver	0.3368	0.2075	1.62	0.105	0.3935	0.2402	1.64	0.101
Relocation Asset Driver	0.4791	0.2069	2.32	**0.021**	0.2682	0.2242	1.2	0.232
Relocation Cost Driver	-0.2039	0.2145	-0.95	0.342	-0.4219	0.2418	-1.74	**0.081**
Relocation Productivity Driver	0.1226	0.2211	0.55	0.579	0.2761	0.2764	1	0.318
Industry 4.0	-1.6098	2.1045	-0.76	0.444	-1.4879	1.8579	-0.8	0.423
Industry 4.0 → Productivity	***2.8323***	***4.3138***	***0.66***	***0.511***	***1.5756***	***3.8066***	***0.41***	***0.679***
Crisis 08-11	0.4935	0.4193	1.18	0.239	1.1219	0.5321	2.11	**0.035**
Crisis 12-15	0.5197	0.5019	1.04	0.3	1.0248	0.6110	1.68	**0.093**
Size Total Asset	0.0017	0.1375	0.01	0.99	0.1739	0.1470	1.18	0.237
Host1, East-EU	-0.5781	0.6911	-0.84	0.403	-1.1665	0.9552	-1.22	0.222
Host2/Home, East-EU	-2.7094	0.7828	-3.46	**0.001**	-3.0367	0.9475	-3.2	**0.001**
Euro Currency	-0.4915	0.4714	-1.04	0.297	-0.7363	0.6831	-1.08	0.281
High Tech Control	0.0028	0.3953	0.01	0.994	0.3511	0.5064	0.69	0.488
Patents in FIR	-0.0842	0.1804	-0.47	0.641	-0.0441	0.1724	-0.26	0.798

Interaction between Asset Seeking and Industry 4.0	Sample				EU-HQ			
	Coef.	R. Std. Err.	z	P>z	Coef.	R. Std. Err.	z	P>z
Relocation Market Driver	0.3387	0.2092	1.62	0.105	0.3546	0.2447	1.45	0.147
Relocation Asset Driver	0.5335	0.2151	2.48	**0.013**	0.3080	0.2260	1.36	0.173
1.Industry 4.0	0.5431	0.9508	0.57	0.568	1.1850	1.9990	0.59	0.553
Industry 4.0 → Asset	***-1.3588***	***0.8059***	***-1.69***	***0.092***	***-1.9537***	***1.2457***	***-1.57***	***0.117***
Relocation Cost Driver	-0.1911	0.2180	-0.88	0.381	-0.3998	0.2420	-1.65	**0.099**
Relocation Productivity Driver	0.1266	0.2208	0.57	0.566	0.2625	0.2768	0.95	0.343
Crisis 08-11	0.4974	0.4205	1.18	0.237	1.0629	0.5269	2.02	**0.044**
Crisis 12-15	0.5024	0.5025	1	0.317	0.9953	0.6190	1.61	0.108
Size Total Asset	-0.0112	0.1426	-0.08	0.937	0.1677	0.1433	1.17	0.242
Host1, East-EU	-0.6035	0.6930	-0.87	0.384	-1.1374	0.9496	-1.2	0.231
Host2/Home, East-EU	-2.6474	0.7779	-3.4	**0.001**	-2.9720	0.9308	-3.19	**0.001**
Euro Currency	-0.4535	0.4747	-0.96	0.339	-0.7204	0.6834	-1.05	0.292
High Tech Control	0.0078	0.3954	0.02	0.984	0.2783	0.5189	0.54	0.592
Patents in FIR	-0.1835	0.1974	-0.93	0.353	-0.1014	0.2195	-0.46	0.644

Table 0.4 - Results of the interaction logit models for Industry4.0. Second host/home vs First host country

Annex 4: Breakdown of the variables

Variables in the first specification: Differences between First host country and Home country

Patents and Industry 4.0

	ERM Sample	Correlation Matrix													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	RHC (Dependent Variable)	1.0000													
2	Offshoring Market Driver	0.3008	1.0000												
3	Offshoring Asset Driver	0.1493	0.2422	1.0000											
4	Offshoring Cost Driver	-0.1255	-0.0884	-0.2749	1.0000										
5	Offshoring Productivity Driver	-0.3649	-0.0350	0.0655	-0.0381	1.0000									
6	Crisis 08-11	0.0525	-0.0432	-0.0856	-0.0875	-0.0517	1.0000								
7	Crisis 12-15	0.0428	0.0797	0.1113	-0.0598	-0.0226	-0.3445	1.0000							
8	Size Total Assets	0.0800	-0.1699	-0.1533	0.0509	-0.1408	0.0170	-0.0101	1.0000						
9	Host1, East-EU	0.0086	-0.0784	-0.3546	0.1550	-0.3440	0.0944	-0.0625	0.0857	1.0000					
10	Host2/Home, East-EU	-0.5212	-0.1487	-0.1489	0.0334	0.6173	0.0207	-0.0459	-0.1077	0.0853	1.0000				
11	Euro-Currency	-0.0475	0.1054	-0.0307	-0.1353	0.2326	-0.1347	0.0217	-0.0166	-0.5017	-0.0370	1.0000			
12	High-Tech Control	-0.0474	-0.0608	-0.2255	0.1541	-0.0134	-0.1016	-0.0540	0.0026	-0.0221	0.0756	0.0175	1.0000		
13	Industry 4.0	-0.0307	-0.0401	-0.1364	0.1652	0.0058	-0.0217	-0.0383	0.2521	0.0330	0.0326	-0.0032	0.1559	1.0000	
14	Patents in FIR technologies	0.0897	0.0007	0.0361	0.0268	-0.0597	-0.0227	0.2399	-0.0160	-0.0804	-0.1986	0.0916	-0.0479	0.0974	1.0000
	Obs	261	261	261	261	261	261	261	261	261	261	261	261	261	261
	Mean	0.2414	0.1499	-0.0471	0.0093	-0.0804	0.2759	0.2375	0.0623	0.1533	0.5249	0.6590	0.6743	0.0327	0.0345
	Std. Dev.	0.4287	0.9139	1.0670	0.9816	1.1072	0.4478	0.4264	1.0845	0.3609	0.5003	0.4750	0.4695	1.0166	0.1828
	Min	0	-1.7723	-2.2366	-3.0849	-5.7679	0	0	-0.5452	0	0	0	0	-0.2548	0
	Max	1	1.2567	2.9651	3.4473	6.0394	1	1	7.8901	1	1	1	1	6.8149	1

	ERM Sample	Correlation Matrix													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	RHC (Dependent Variable)	1.0000													
2	Offshoring Market Driver	-0.0488	1.0000												
3	Offshoring Asset Driver	0.0399	0.0723	1.0000											
4	Offshoring Cost Driver	-0.0917	-0.0375	-0.1421	1.0000										
5	Offshoring Productivity Driver	-0.4095	0.0004	0.0594	0.0007	1.0000									
6	Crisis 08-11	0.0803	0.1352	-0.1495	-0.0325	-0.0502	1.0000								
7	Crisis 12-15	0.0193	0.1048	0.0529	0.1050	-0.0320	-0.3593	1.0000							
8	Size Total Assets	0.1609	-0.1889	-0.1263	-0.0176	-0.1977	-0.0241	-0.0241	1.0000						
9	Host1, East-EU	0.0074	-0.3513	-0.3356	0.0902	-0.3710	0.1325	-0.0356	0.1751	1.0000					
10	Host2/Home, East-EU	-0.5829	0.0040	-0.0397	0.0139	0.6137	0.0503	0.0218	-0.1225	0.0605	1.0000				
11	Euro-Currency	-0.0857	0.2409	0.0080	-0.0883	0.2578	-0.1821	0.0207	-0.0632	-0.5464	-0.0357	1.0000			
12	High-Tech Control	-0.0229	-0.0068	-0.2230	0.0500	0.0199	-0.0956	-0.0062	0.1037	-0.1176	0.1052	0.0261	1.0000		
13	Industry 4.0	-0.0165	-0.2392	-0.0919	0.1288	-0.0007	0.0153	-0.0329	0.2015	0.0298	0.0574	-0.0811	0.1234	1.0000	
14	Patents in FIR technologies	0.0892	-0.0426	0.0020	0.0593	-0.0481	-0.0587	0.2798	0.0064	-0.0877	-0.1845	0.0806	-0.0335	0.1511	1.0000
	Obs	174	174	174	174	174	174	174	174	174	174	174	174	174	174
	Mean	0.3621	0.6538	0.1787	-0.1064	-0.1471	0.2701	0.2586	-0.0274	0.1552	0.4483	0.6724	0.6494	0.0003	0.0402
	Std. Dev.	0.4820	0.2716	1.0612	0.8424	1.1959	0.4453	0.4391	1.1417	0.3631	0.4988	0.4707	0.4785	1.0491	0.1971
	Min	0	0.1883	-2.1781	-3.0849	-5.7679	0	0	-0.5452	0	0	0	0	-0.255	0
	Max	1	1.2567	2.9651	1.6953	6.0394	1	1	7.8901	1	1	1	1	6.8149	1

Table 0.5 - Summary Statistics and Correlation Matrix. Specification with Patents and Industry 4.0. First Host vs Home Country

Industry 4.0 Only

ERM Sample		Correlation Matrix												
		1	2	3	4	5	6	7	8	9	10	11	12	13
1	RHC (Dependent Variable)	1.0000												
2	Offshoring Market Driver	0.2782	1.0000											
3	Offshoring Asset Driver	0.1697	0.2302	1.0000										
4	Offshoring Cost Driver	-0.1252	-0.1045	-0.2599	1.0000									
5	Offshoring Productivity Driver	-0.3670	-0.0247	0.0750	-0.0336	1.0000								
6	Crisis 08-11	0.0707	-0.0355	-0.0760	-0.0929	-0.0345	1.0000							
7	Crisis 12-15	0.0349	0.0528	0.0849	-0.0565	-0.0390	-0.3471	1.0000						
8	Size Total Assets	0.0571	-0.1722	-0.1519	0.0708	-0.1169	-0.0066	-0.0108	1.0000					
9	Host1, East-EU	-0.0127	-0.0531	-0.3808	0.1339	-0.3564	0.0875	-0.0460	0.0517	1.0000				
10	Host2/Home, East-EU	-0.5154	-0.1228	-0.1615	0.0297	0.5945	0.0338	-0.0385	-0.1147	0.1241	1.0000			
11	Euro-Currency	-0.0613	0.1015	-0.0030	-0.1426	0.2609	-0.1170	0.0071	-0.0050	-0.5102	-0.0413	1.0000		
12	High-Tech Control	-0.0274	-0.0697	-0.2101	0.1686	-0.0123	-0.0495	-0.0458	-0.0067	-0.0055	0.0911	0.0033	1.0000	
13	Industry 4.0	0.1142	-0.0014	0.0135	0.0289	-0.0600	0.0058	0.2103	-0.0172	-0.0842	-0.1997	0.0939	-0.0205	1.0000
	Obs	290	290	290	290	290	290	290	290	290	290	290	290	290
	Mean	0.2414	0.1982	-0.0403	-0.0276	-0.0801	0.2862	0.2310	0.0353	0.1655	0.5276	0.6655	0.6517	0.0345
	Std. Dev.	0.4287	0.8922	1.0706	0.9580	1.0803	0.4528	0.4222	1.0622	0.3723	0.5001	0.4726	0.4772	0.1828
	Min	0	-1.7723	-2.2366	-3.0849	-5.7679	0	0	-0.5452	0	0	0	0	0
	Max	1	1.2567	2.9651	3.4473	6.0394	1	1	7.8901	1	1	1	1	1

EU Subsample		Correlation Matrix												
		1	2	3	4	5	6	7	8	9	10	11	12	13
1	RHC (Dependent Variable)	1.0000												
2	Offshoring Market Driver	-0.0686	1.0000											
3	Offshoring Asset Driver	0.0840	0.0718	1.0000										
4	Offshoring Cost Driver	-0.0858	-0.0342	-0.1271	1.0000									
5	Offshoring Productivity Driver	-0.4112	0.0139	0.0707	0.0028	1.0000								
6	Crisis 08-11	0.0897	0.0517	-0.1327	-0.0452	-0.0269	1.0000							
7	Crisis 12-15	0.0248	0.1083	0.0315	0.0904	-0.0499	-0.3592	1.0000						
8	Size Total Assets	0.1289	-0.1786	-0.1227	0.0130	-0.1644	-0.0498	-0.0230	1.0000					
9	Host1, East-EU	-0.0310	-0.3158	-0.3855	0.0760	-0.3816	0.1142	-0.0150	0.1192	1.0000				
10	Host2/Home, East-EU	-0.5751	0.0168	-0.0797	0.0065	0.5809	0.0660	0.0277	-0.1340	0.1236	1.0000			
11	Euro-Currency	-0.0997	0.2285	0.0408	-0.1045	0.2964	-0.1484	-0.0058	-0.0393	-0.5526	-0.0372	1.0000		
12	High-Tech Control	0.0072	-0.0176	-0.1940	0.0812	0.0111	-0.0266	0.0104	0.0710	-0.0765	0.1099	0.0119	1.0000	
13	Industry 4.0	0.1188	-0.0559	-0.0235	0.0606	-0.0504	-0.0167	0.2404	0.0029	-0.0930	-0.1895	0.0855	0.0005	1.0000
	Obs	202	202	202	202	202	202	202	202	202	202	202	202	202
	Mean	0.3465	0.6624	0.1579	-0.1433	-0.1341	0.2871	0.2426	-0.0521	0.1733	0.4653	0.6782	0.6238	0.0396
	Std. Dev.	0.4770	0.2651	1.0707	0.8210	1.1499	0.4535	0.4297	1.1031	0.3794	0.5000	0.4683	0.4856	0.1955
	Min	0	0.1883	-2.1781	-3.0849	-5.7679	0	0	-0.5452	0	0	0	0	0
	Max	1	1.2567	2.9651	1.6953	6.0394	1	1	7.8901	1	1	1	1	1

Table 0.6 - Summary Statistics and Correlation Matrix. Specification with Industry 4.0 only. First Host vs Home Country

Patents only

	ERM Sample	Correlation Matrix 1	2	3	4	5	6	7	8	9	10	11	12	13
1	RHC (Dependent Variable)	1.0000												
2	Offshoring Market Driver	0.3026	1.0000											
3	Offshoring Asset Driver	0.1499	0.2431	1.0000										
4	Offshoring Cost Driver	-0.1273	-0.0939	-0.2756	1.0000									
5	Offshoring Productivity Driver	-0.3640	-0.0332	0.0658	-0.0390	1.0000								
6	Crisis 08-11	0.0538	-0.0392	-0.0847	-0.0897	-0.0510	1.0000							
7	Crisis 12-15	0.0440	0.0826	0.1120	-0.0618	-0.0220	-0.3427	1.0000						
8	Size Total Assets	0.0811	-0.1657	-0.1525	0.0487	-0.1402	0.0183	-0.0089	1.0000					
9	Host1, East-EU	0.0095	-0.0754	-0.3538	0.1530	-0.3434	0.0953	-0.0616	0.0865	1.0000				
10	Host2/Home, East-EU	-0.5220	-0.1535	-0.1499	0.0369	0.6152	0.0184	-0.0478	-0.1094	0.0836	1.0000			
11	Euro-Currency	-0.0444	0.1130	-0.0288	-0.1398	0.2331	-0.1308	0.0245	-0.0136	-0.4974	-0.0418	1.0000		
12	High-Tech Control	-0.0489	-0.0647	-0.2262	0.1563	-0.0141	-0.1030	-0.0553	0.0011	-0.0232	0.0779	0.0138	1.0000	
13	Patents in FIR technologies	-0.0301	-0.0382	-0.1359	0.1638	0.0061	-0.0210	-0.0377	0.2525	0.0335	0.0316	-0.0018	0.1550	1.0000
	Obs	262	262	262	262	262	262	262	262	262	262	262	262	262
	Mean	0.2405	0.1443	-0.0485	0.0130	-0.0816	0.2748	0.2366	0.0600	0.1527	0.5267	0.6565	0.6756	0.0317
	Std. Dev.	0.4282	0.9166	1.0652	0.9816	1.1052	0.4473	0.4258	1.0831	0.3604	0.5002	0.4758	0.4691	1.0148
	Min	0	-1.7723	-2.2366	-3.0849	-5.7679	0	0	-0.5452	0	0	0	0	-0.255
	Max	1	1.2567	2.9651	3.4473	6.0394	1	1	7.8901	1	1	1	1	6.8149

	EU Subsample	Correlation Matrix 1	2	3	4	5	6	7	8	9	10	11	12	13
1	RHC (Dependent Variable)	1.0000												
2	Offshoring Market Driver	-0.0488	1.0000											
3	Offshoring Asset Driver	0.0399	0.0723	1.0000										
4	Offshoring Cost Driver	-0.0917	-0.0375	-0.1421	1.0000									
5	Offshoring Productivity Driver	-0.4095	0.0004	0.0594	0.0007	1.0000								
6	Crisis 08-11	0.0803	0.1352	-0.1495	-0.0325	-0.0502	1.0000							
7	Crisis 12-15	0.0193	0.1048	0.0529	0.1050	-0.0320	-0.3593	1.0000						
8	Size Total Assets	0.1609	-0.1889	-0.1263	-0.0176	-0.1977	-0.0241	-0.0241	1.0000					
9	Host1, East-EU	0.0074	-0.3513	-0.3356	0.0902	-0.3710	0.1325	-0.0356	0.1751	1.0000				
10	Host2/Home, East-EU	-0.5829	0.0040	-0.0397	0.0139	0.6137	0.0503	0.0218	-0.1225	0.0605	1.0000			
11	Euro-Currency	-0.0857	0.2409	0.0080	-0.0883	0.2578	-0.1821	0.0207	-0.0632	-0.5464	-0.0357	1.0000		
12	High-Tech Control	-0.0229	-0.0068	-0.2230	0.0500	0.0199	-0.0956	-0.0062	0.1037	-0.1176	0.1052	0.0261	1.0000	
13	Patents in FIR technologies	-0.0165	-0.2392	-0.0919	0.1288	-0.0007	0.0153	-0.0329	0.2015	0.0298	0.0574	-0.0811	0.1234	1.0000
	Obs	174	174	174	174	174	174	174	174	174	174	174	174	174
	Mean	0.3621	0.6538	0.1787	-0.1064	-0.1471	0.2701	0.2586	-0.0274	0.1552	0.4483	0.6724	0.6494	0.0003
	Std. Dev.	0.4820	0.2716	1.0612	0.8424	1.1959	0.4453	0.4391	1.1417	0.3631	0.4988	0.4707	0.4785	1.0491
	Min	0	0.1883	-2.1781	-3.0849	-5.7679	0	0	-0.5452	0	0	0	0	-0.255
	Max	1	1.2567	2.9651	1.6953	6.0394	1	1	7.8901	1	1	1	1	6.8149

Table 0.7 - Summary Statistics and Correlation Matrix. Specification with Patents in FIR only. First Host vs Home Country

Variables in the second specification: Differences in second host/home and first host country

Industry 4.0 and Patents

ERM Sample		Correlation Matrix													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	RHC (Dependent Variable)	1.0000													
2	Relocation Market Driver	0.2907	1.0000												
3	Relocation Asset Driver	0.3225	0.0650	1.0000											
4	Relocation Cost Driver	0.1698	0.0997	0.2065	1.0000										
5	Relocation Productivity Driver	0.3605	0.2985	0.4426	0.3548	1.0000									
6	Crisis 08-11	0.0525	0.0058	-0.0178	0.0013	0.0571	1.0000								
7	Crisis 12-15	0.0435	-0.0776	-0.0668	0.0966	0.0182	-0.3447	1.0000							
8	Size Total Assets	0.0861	0.1738	0.1220	0.0961	0.1436	0.0270	-0.0364	1.0000						
9	Host1, East-EU	0.0175	0.2415	0.2189	0.0257	0.3630	0.1104	-0.0778	0.0608	1.0000					
10	Host2/Home, East-EU	-0.5178	-0.4365	-0.4616	-0.3603	-0.6127	0.0219	-0.0470	-0.1179	0.0732	1.0000				
11	Euro-Currency	-0.0559	-0.1714	0.0868	-0.1455	-0.2508	-0.1335	0.0274	-0.0031	-0.4945	-0.0247	1.0000			
12	High-Tech Control	-0.0513	-0.0113	-0.0127	-0.0008	0.0076	-0.0944	-0.0450	0.0203	-0.0171	0.0825	0.0040	1.0000		
13	Industry 4.0	-0.0314	0.0945	-0.0267	-0.1288	-0.0084	-0.0201	-0.0431	0.2512	0.0319	0.0338	-0.0037	0.1594	1.0000	
14	Patents in FIR technologies	0.0883	0.1135	0.1024	0.0425	0.0574	-0.0230	0.2420	-0.0150	-0.0794	-0.1973	0.0902	-0.0495	0.0973	1.0000
	Obs	257	257	257	257	257	257	257	257	257	257	257	257	257	257
	Mean	0.2451	0.0520	0.1329	-0.0497	0.0967	0.2763	0.2374	0.0545	0.1479	0.5175	0.6654	0.6770	0.0337	0.0350
	Std. Dev.	0.4310	1.0252	1.0228	1.0491	1.1064	0.4480	0.4263	1.0692	0.3557	0.5007	0.4728	0.4685	1.0238	0.1842
	Min	0	-2.1877	-3.1187	-4.6478	-6.0394	0	0	-0.5452	0	0	0	0	-0.2548	0
	Max	1	2.4040	3.1950	1.8545	5.7679	1	1	7.8901	1	1	1	1	6.8149	1

ERM Sample		Correlation Matrix													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	RHC (Dependent Variable)	1.0000													
2	Relocation Market Driver	0.3190	1.0000												
3	Relocation Asset Driver	0.3265	0.0174	1.0000											
4	Relocation Cost Driver	0.1898	0.1583	0.2385	1.0000										
5	Relocation Productivity Driver	0.4053	0.2313	0.4435	0.4007	1.0000									
6	Crisis 08-11	0.0859	-0.0322	0.0311	0.0047	0.0641	1.0000								
7	Crisis 12-15	0.0244	-0.1201	-0.0463	0.0905	0.0314	-0.3543	1.0000							
8	Size Total Assets	0.1787	0.2149	0.1228	0.0891	0.2090	-0.0092	-0.0588	1.0000						
9	Host1, East-EU	0.0161	0.2578	0.2221	0.0927	0.3818	0.1484	-0.0614	0.1377	1.0000					
10	Host2/Home, East-EU	-0.5792	-0.4050	-0.5176	-0.3919	-0.6100	0.0443	0.0150	-0.1453	0.0494	1.0000				
11	Euro-Currency	-0.0997	-0.2243	0.0126	-0.1947	-0.2791	-0.1772	0.0306	-0.0424	-0.5459	-0.0175	1.0000			
12	High-Tech Control	-0.0353	-0.0674	-0.0535	0.0667	-0.0357	-0.0891	0.0026	0.1304	-0.1054	0.1250	0.0035	1.0000		
13	Industry 4.0	-0.0157	0.0829	-0.0724	-0.1235	-0.0004	0.0193	-0.0385	0.1989	0.0237	0.0566	-0.0804	0.1264	1.0000	
14	Patents in FIR technologies	0.0877	0.1340	0.1094	0.0515	0.0462	-0.0580	0.2839	0.0099	-0.0869	-0.1833	0.0781	-0.0371	0.1515	1.0000
	Obs	172	172	172	172	172	172	172	172	172	172	172	172	172	172
	Mean	0.3663	0.1219	0.2275	-0.0007	0.1604	0.2674	0.2558	-0.0453	0.1512	0.4419	0.6802	0.6570	-0.0009	0.0407
	Std. Dev.	0.4832	1.0806	1.1283	1.0564	1.1943	0.4439	0.4376	1.1139	0.3593	0.4981	0.4677	0.4761	1.0545	0.1982
	Min	0	-2.1877	-3.1187	-4.6478	-6.0394	0	0	-0.5452	0	0	0	0	-0.2548	0
	Max	1	2.4040	3.1950	1.8545	5.7679	1	1	7.8901	1	1	1	1	6.8149	1

Table 0.8 - Summary Statistics and Correlation Matrix. Specification with Patents and Industry 4.0. Second host/home vs First host country

Industry 4.0 only

	ERM Sample	Correlation Matrix 1	2	3	4	5	6	7	8	9	10	11	12	13
1	RHC (Dependent Variable)	1.0000												
2	Relocation Market Driver	0.2986	1.0000											
3	Relocation Asset Driver	0.3074	0.0746	1.0000										
4	Relocation Cost Driver	0.1508	0.0756	0.1965	1.0000									
5	Relocation Productivity Driver	0.3630	0.3081	0.4280	0.3308	1.0000								
6	Crisis 08-11	0.0707	0.0353	-0.0224	-0.0243	0.0388	1.0000							
7	Crisis 12-15	0.0356	-0.0696	-0.0637	0.0996	0.0354	-0.3473	1.0000						
8	Size Total Assets	0.0625	0.1714	0.1219	0.0953	0.1192	0.0020	-0.0353	1.0000					
9	Host1, East-EU	-0.0057	0.2306	0.2216	0.0023	0.3727	0.1013	-0.0591	0.0282	1.0000				
10	Host2/Home, East-EU	-0.5123	-0.4288	-0.4269	-0.3401	-0.5900	0.0353	-0.0396	-0.1246	0.1150	1.0000			
11	Euro-Currency	-0.0691	-0.1756	0.0650	-0.1324	-0.2784	-0.1160	0.0122	0.0082	-0.5041	-0.0302	1.0000		
12	High-Tech Control	-0.0302	-0.0213	-0.0028	-0.0015	0.0077	-0.0425	-0.0376	0.0087	-0.0015	0.0968	-0.0084	1.0000	
13	Industry 4.0	0.1130	0.1226	0.1284	0.0444	0.0579	0.0056	0.2120	-0.0163	-0.0833	-0.1985	0.0927	-0.0215	1.0000
	Obs	286	286	286	286	286	286	286	286	286	286	286	286	286
	Mean	0.2448	0.0439	0.1189	-0.0499	0.0948	0.2867	0.2308	0.0279	0.1608	0.5210	0.6713	0.6538	0.0350
	Std. Dev.	0.4307	1.0050	1.0042	1.0197	1.0793	0.4530	0.4221	1.0476	0.3680	0.5004	0.4706	0.4766	0.1840
	Min	0	-2.1877	-3.1187	-4.6478	-6.0394	0	0	-0.5452	0	0	0	0	0
	Max	1	2.4040	3.1950	1.8545	5.7679	1	1	7.8901	1	1	1	1	1

	EU Subsample	Correlation Matrix 1	2	3	4	5	6	7	8	9	10	11	12	13
1	RHC (Dependent Variable)	1.0000												
2	Relocation Market Driver	0.3343	1.0000											
3	Relocation Asset Driver	0.3113	0.0400	1.0000										
4	Relocation Cost Driver	0.1655	0.1207	0.2248	1.0000									
5	Relocation Productivity Driver	0.4077	0.2479	0.4290	0.3652	1.0000								
6	Crisis 08-11	0.0941	0.0146	0.0135	-0.0335	0.0384	1.0000							
7	Crisis 12-15	0.0295	-0.1132	-0.0352	0.0958	0.0500	-0.3548	1.0000						
8	Size Total Assets	0.1437	0.2103	0.1221	0.0898	0.1738	-0.0373	-0.0552	1.0000					
9	Host1, East-EU	-0.0251	0.2406	0.2193	0.0484	0.3900	0.1271	-0.0362	0.0859	1.0000				
10	Host2/Home, East-EU	-0.5721	-0.3963	-0.4718	-0.3598	-0.5774	0.0618	0.0216	-0.1544	0.1164	1.0000			
11	Euro-Currency	-0.1117	-0.2287	-0.0062	-0.1720	-0.3160	-0.1441	0.0030	-0.0194	-0.5528	-0.0220	1.0000		
12	High-Tech Control	-0.0022	-0.0642	-0.0367	0.0610	-0.0241	-0.0209	0.0184	0.0927	-0.0667	0.1255	-0.0069	1.0000	
13	Industry 4.0	0.1177	0.1455	0.1407	0.0536	0.0488	-0.0158	0.2438	0.0059	-0.0924	-0.1884	0.0835	-0.0021	1.0000
	Obs	200	200	200	200	200	200	200	200	200	200	200	200	200
	Mean	0.3500	0.0949	0.1980	-0.0089	0.1454	0.2850	0.2400	-0.0678	0.1700	0.4600	0.6850	0.6300	0.0400
	Std. Dev.	0.4782	1.0458	1.0923	1.0161	1.1481	0.4525	0.4282	1.0777	0.3766	0.4996	0.4657	0.4840	0.1965
	Min	0	-2.1877	-3.1187	-4.6478	-6.0394	0	0	-0.5452	0	0	0	0	0
	Max	1	2.4040	3.1950	1.8545	5.7679	1	1	7.8901	1	1	1	1	1

Table 0.9 - Summary Statistics and Correlation Matrix. Specification with Industry 4.0 only. Second host/home vs First host country

Patents Only

	ERM Sample	Correlation Matrix												
		1	2	3	4	5	6	7	8	9	10	11	12	13
1	RHC (Dependent Variable)	1.0000												
2	Relocation Market Driver	0.2907	1.0000											
3	Relocation Asset Driver	0.3225	0.0650	1.0000										
4	Relocation Cost Driver	0.1698	0.0997	0.2065	1.0000									
5	Relocation Productivity Driver	0.3605	0.2985	0.4426	0.3548	1.0000								
6	Crisis 08-11	0.0525	0.0058	-0.0178	0.0013	0.0571	1.0000							
7	Crisis 12-15	0.0435	-0.0776	-0.0668	0.0966	0.0182	-0.3447	1.0000						
8	Size Total Assets	0.0861	0.1738	0.1220	0.0961	0.1436	0.0270	-0.0364	1.0000					
9	Host1, East-EU	0.0175	0.2415	0.2189	0.0257	0.3630	0.1104	-0.0778	0.0608	1.0000				
10	Host2/Home, East-EU	-0.5178	-0.4365	-0.4616	-0.3603	-0.6127	0.0219	-0.0470	-0.1179	0.0732	1.0000			
11	Euro-Currency	-0.0559	-0.1714	0.0868	-0.1455	-0.2508	-0.1335	0.0274	-0.0031	-0.4945	-0.0247	1.0000		
12	High-Tech Control	-0.0513	-0.0113	-0.0127	-0.0008	0.0076	-0.0944	-0.0450	0.0203	-0.0171	0.0825	0.0040	1.0000	
13	Patents in FIR technologies	-0.0314	0.0945	-0.0267	-0.1288	-0.0084	-0.0201	-0.0431	0.2512	0.0319	0.0338	-0.0037	0.1594	1.0000
	Obs	257	257	257	257	257	257	257	257	257	257	257	257	257
	Mean	0.2451	0.0520	0.1329	-0.0497	0.0967	0.2763	0.2374	0.0545	0.1479	0.5175	0.6654	0.6770	0.0337
	Std. Dev.	0.4310	1.0252	1.0228	1.0491	1.1064	0.4480	0.4263	1.0692	0.3557	0.5007	0.4728	0.4685	1.0238
	Min	0	-2.1877	-3.1187	-4.6478	-6.0394	0	0	-0.5452	0	0	0	0	-0.2548
	Max	1	2.4040	3.1950	1.8545	5.7679	1	1	7.8901	1	1	1	1	6.8149

	EU Subsample	Correlation Matrix												
		1	2	3	4	5	6	7	8	9	10	11	12	13
1	RHC (Dependent Variable)	1.0000												
2	Relocation Market Driver	0.3190	1.0000											
3	Relocation Asset Driver	0.3265	0.0174	1.0000										
4	Relocation Cost Driver	0.1898	0.1583	0.2385	1.0000									
5	Relocation Productivity Driver	0.4053	0.2313	0.4435	0.4007	1.0000								
6	Crisis 08-11	0.0859	-0.0322	0.0311	0.0047	0.0641	1.0000							
7	Crisis 12-15	0.0244	-0.1201	-0.0463	0.0905	0.0314	-0.3543	1.0000						
8	Size Total Assets	0.1787	0.2149	0.1228	0.0891	0.2090	-0.0092	-0.0588	1.0000					
9	Host1, East-EU	0.0161	0.2578	0.2221	0.0927	0.3818	0.1484	-0.0614	0.1377	1.0000				
10	Host2/Home, East-EU	-0.5792	-0.4050	-0.5176	-0.3919	-0.6100	0.0443	0.0150	-0.1453	0.0494	1.0000			
11	Euro-Currency	-0.0997	-0.2243	0.0126	-0.1947	-0.2791	-0.1772	0.0306	-0.0424	-0.5459	-0.0175	1.0000		
12	High-Tech Control	-0.0353	-0.0674	-0.0535	0.0667	-0.0357	-0.0891	0.0026	0.1304	-0.1054	0.1250	0.0035	1.0000	
13	Patents in FIR technologies	-0.0157	0.0829	-0.0724	-0.1235	-0.0004	0.0193	-0.0385	0.1989	0.0237	0.0566	-0.0804	0.1264	1.0000
	Obs	172	172	172	172	172	172	172	172	172	172	172	172	172
	Mean	0.3663	0.1219	0.2275	-0.0007	0.1604	0.2674	0.2558	-0.0453	0.1512	0.4419	0.6802	0.6570	-0.0009
	Std. Dev.	0.4832	1.0806	1.1283	1.0564	1.1943	0.4439	0.4376	1.1139	0.3593	0.4981	0.4677	0.4761	1.0545
	Min	0	-2.1877	-3.1187	-4.6478	-6.0394	0	0	-0.5452	0	0	0	0	-0.2548
	Max	1	2.4040	3.1950	1.8545	5.7679	1	1	7.8901	1	1	1	1	6.8149

Table 0.10 - Summary Statistics and Correlation Matrix. Specification with Patents in FIR only. Second host/home vs First host country

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