Formal and Strategic Appropriability Strategies of Multinational Firms – A Cross Country Comparison

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Abstract

International knowledge spillovers, especially through multinational companies (MNCs), have recently been a major topic of discussion among academics and practitioners. Most research in this field focuses on knowledge sharing activities of MNC subsidiaries. Relatively little is known about their capabilities for protecting valuable knowledge from spilling over to host country competitors. We extend this stream of research by investigating MNC appropriability strategies that go beyond formal methods (patents, copyrights, trademarks) to include strategic ones (secrecy, lead time, complex design). We conceptualize the breadth and depth of a firm's knowledge protection strategies and relate them to the particular situation of MNC subsidiaries. Moreover, we argue that their approaches differ with regard to host country challenges and opportunities. We address these issues empirically, based on a harmonized survey of innovation activities of more than 1,800 firms located in Portugal and Germany. We find that MNCs prefer broader sets of appropriability strategies in host countries with fewer opportunities for knowledge sourcing. However, munificent host country environments require targeted sets of appropriability strategies instead. We deduce that these results are due to a need for reciprocity to benefit fully from promising host country knowledge flows.

Keywords: Appropriability, Multinational Companies, Patenting

JEL-Classification: F23, O31, O32, D83

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1 Introduction

Global economic growth tends to be spurred by international knowledge transfers (Romer, 1990). Multinational companies (MNCs) and their international subsidiaries have been identified as major channels for these knowledge flows (see for example Kogut and Zander, 1993). Against this background, innovation activities of MNCs abroad have been an important theme of discussion for both academics and practitioners. International business literature has primarily focused on MNC knowledge sourcing in host countries (e.g. Almeida and Phene, 2004) while international economics literature concentrates on spillovers from MNCs to host country firms (e.g. Keller, 2002). The topic has also caught the attention of policy-makers, prompting many governments to provide substantial financial support for MNC investment in their country or region (e.g. Daimler AG investing in Alabama; Haskel et al., 2007).

However, as Alcácer and Chung (2007) point out, and despite the increasing number of international patenting activities (Yang and Kuo, 2008), research has paid relatively little attention to MNC strategies for preventing knowledge spillovers or has treated MNC subsidiaries as rather passive actors in host country knowledge exchanges. One reason for this discrepancy may be that major studies in the field of international economics and business research use patenting, the most prominent form of appropriability, to trace knowledge spillovers, instead of inquiring about firms' strategies to protect knowledge (e.g. Audretsch and Feldman, 1996; Jaffe et al., 1993). Our goal is to contribute to addressing this lack of analysis of MNC knowledge management strategies by investigating the appropriability strategies of MNC subsidiaries. More precisely, we focus on the protection methods that firms put in place to shield their knowledge from spilling over to competitors. If successful, these protection methods enable firms to appropriate the economic returns from their investments in knowledge production through R&D activities (Arrow, 1962). We go beyond formal forms of appropriability (patents, copyrights, trademarks), which rest upon legal protection, and include strategic ones (secrecy, lead time, complex design), which are built around organisational arrangements. These appropriability strategies vary widely with regard to how firms are able to apply them (e.g. firm size) and their effectiveness in protecting knowledge (e.g. Harabi, 1995). Hence, we consider the various forms of appropriability instruments a firm may use to generate breadth and depth in its appropriability strategy and connect this discussion to the specific needs and opportunities of MNCs. In addition, we argue that these arrangements reflect different host country threats and opportunities in knowledge exchange. We address these issues empirically with data from the European Community Innovation Survey (CIS) for more than 1,800 firms from Portugal and Germany. The harmonized survey provides us with the unique opportunity to compare MNC appropriability strategies in host country environments that differ significantly.

This paper is structured as follows. Section 2 presents our conceptual framework of international knowledge flows and appropriability methods. We develop hypotheses based on

this discussion in section 3. Section 4 presents the empirical study for testing these hypotheses; the results follow in section 5. We discuss them in section 6, draw conclusions and suggest some pathways for future research.

2 Conceptual framework

Relatively few countries generate most of the world's new technologies. The seven most industrialized countries (G7) accounted for 84% of global R&D expenditure in 1995 (Keller, 2004) and still 80% in 2005 (OECD, 2007). Only a limited number of countries, such as South Korea, have been able to catch up in recent years (Furman and Hayes, 2004; Mahmood and Singh, 2003). International knowledge spillovers are therefore an important source of knowledge for many countries and can drive growth not only at the location where they are generated, but globally (Romer, 1990). MNCs and their international subsidiaries have been recognized as important transmission channels for this knowledge transfer. The advantages of multinational firms for transferring knowledge across borders have been conceptualized in several ways, such as the internalization of transaction costs (e.g. Buckley and Casson, 1981), differentiated networks that provide a fit with varying environmental and resource contingencies (e.g. Ghoshal and Nohria, 1989) or social communities spanning borders (e.g. Kogut and Zander, 1993). Research in international economics has focused on their potential to transfer knowledge to the host country (see for example Aitken and Harrison, 1999; Keller, 2002; Haskel et al., 2007) while international business literature has chosen a different perspective by emphasizing the role of subsidiaries for accessing knowledge from host countries (see for example Almeida, 1996; Frost, 2001). However, relatively little is known about the active strategies MNCs pursue to prevent these spillovers and appropriate the returns of their R&D. We extend the work of Alcácer and Chung (2007) who focus on host country location strategies and Zhao (2006) who investigates the intra-MNC distribution of R&D activities. We consider a broad set of appropriability mechanisms ranging from patenting to secrecy and complex design. We start out by reviewing important contributions to the research on MNC knowledge spillovers and appropriability strategies.

One of the main processes associated with foreign direct investment is the generation of knowledge and productivity spillovers to national firms. Almeida (1996) analyzed citations of patents belonging to multinational subsidiaries in the USA, to identify learning and sharing aspects of multinational activities. Apart from employment opportunities and capital inflows, these spillovers happen when multinationals create productivity or efficiency benefits in the host country's local firms by increasing competition or introducing new production techniques, work processes, distribution technologies and management or marketing skills (Blomström and Sjöholm, 1999; Aitken and Harrison, 1999). The mechanism through which the spillovers occur differs from industry to industry. New products and processes are the main vehicle of knowledge transfer in industries with rapidly changing technologies and marketing strategies, while organizational skills are more associated with mature industries (Blomström and Kokko, 1998).

Even when multinationals are not interested in producing benefits for host countries, spillovers occur. Because technology and knowledge have many of the properties of public goods, local firms can capture productivity gains through forward or backward linkages with multinationals, imitation, or by hiring workers from multinationals. As stressed by Sanna-Randaccio and Veugelers (2007), these spillovers are larger when multinationals transfer R&D activities to foreign countries, since local firms are then closer to the knowledge source. In addition, the entry of a multinational (either through M&A or greenfield investments) can stimulate local markets. Faced with more intense competition, local firms are compelled to search for new technologies and increase productivity. Crespi et al (2007) analyze the effect of knowledge flows on the productivity of firms in the UK and they conclude that most relevant spillovers are associated with competitors and that multinational presence may be an important source of these spillovers. Finally, given that multinationals have more internationalization skills and are often part of international distribution networks, local firms can benefit from market access spillovers and thus improve their exports (Blomstrom and Kokko, 1998). Kokko (1992) stresses the impact of multinationals on the productivity of local firms by reviewing studies that demonstrated the positive effect of foreign subsidiaries of European firms in less developed countries.

Depending on the host country and industry characteristics, knowledge transfer can take place not only in the industry where the investment is made but also among suppliers and customers within other industries. The nature and intensity of such spillovers depend on country and firm level characteristics, such as the technology gap between the foreign investing firm and local firms and the ownership structure of foreign affiliates (Blomström and Kokko, 1998; Blomström and Sjöholm, 1999).

Another perspective is adopted by international business literature that looks at spillovers from host countries to MNCs. Challenging the seminal work of Vernon (1966) that views the activity of the multinational mainly as the management of knowledge and skills generated in the home base by the parent firm, some literature identifies host country resources as one of the main determinants of a foreign subsidiary's capacity to generate innovations (Frost, 2001). Multinationals have special knowledge creation skills, since they can take advantage of several institutional contexts and technological specializations.

A growing stream of literature shows that MNCs respond positively to strong host country intellectual property rights regimes in their R&D investments. Branstetter et al. (2006) find this relationship for US affiliates with above average patent portfolios in 12 host countries and Belderbos et al. (2006) come to the same conclusion for Japanese MNCs. However, relatively little is known about how MNCs try to prevent these spillovers through appropriability methods. This may be due to the fact that important studies in the field rely on patent statistics, using patents not as an indicator of appropriability strategy but to capture knowledge spillovers based on patent citations (for a review see Keller, 2004). In addition, the use of patents as a knowledge management indicator has several major shortcomings. First, not all patents are innovations and not all innovations are patented (Griliches, 1990). Furthermore, patent activity is rather concentrated. Bloom and Van Reenen (2002) report, for example, that among their sample of almost 60,000 patents by UK firms, 72% were filed by just 12 companies. More importantly, the patent system forces the disclosure and codification

of knowledge in exchange for protection (Gallini, 2002). Cohen et al. (2000) found that in most industries firms do not consider patents as the most important way to protect their innovations. As a result, patent statistics reflect appropriability mechanisms and knowledge spillovers rather selectively.

Alcácer and Chung (2007) address MNCs' knowledge management and appropriability strategies by focussing on the location choices MNCs make in host countries. They find that MNC consider not only the opportunities from incoming knowledge spillovers but also the dangers from outward spillovers, i.e. they choose locations without related industry activity if they expect more outward than inward knowledge flows. Zhao (2006) finds that MNC counter weak institutional protection in host countries by assigning interrelated R&D responsibilities that are only valuable in connection with other internal resources, a strategy that is more efficient in preventing valuable knowledge from spilling over. We extend this stream of research by focussing on a broader set of appropriability strategies by MNC, ranging from formal methods like patents and trade marks to strategic ones like lead time and secrecy.

3 Hypotheses Development

Knowledge generated by R&D and innovation activities has characteristics of public goods, since the investments undertaken and results achieved by one actor may become available to other agents. This process is possible when the reproduction costs for information are low. As described by Adams and Jaffe (1996), knowledge production processes have two different types of effects: one direct, to the firm engaged in the knowledge production activity, and one indirect, to other firms that benefit from the public availability of some of the knowledge. As noted by Nadiri (1993), these knowledge spillovers, which cannot be appropriated by the innovating firm, are substantial and on average close to 50% (varying considerably across industries). Hence firms have strong incentives to protect as much knowledge as possible (Mansfield et al., 1977). Harabi (1995) introduces a framework that distinguishes broadly between two prototypes of appropriability strategies: formal ones (such as patents) and strategic ones (such as lead time). We will discuss both forms of appropriability strategies and examine the major differences between them.

Formal appropriability strategies are built around knowledge protection based on legal intellectual property rights regimes, which grant exclusivity rights to an invention for a certain period of time (Arrow, 1962). Infringements can be punished in court. Patenting is the most prominent form of formal appropriability but protection may also be granted through trademarks, copyrights or design patterns. All of these include a formal process of applying for protection at a government agency (e.g. patent office). This application implies the codification and disclosure of knowledge in exchange for protection once the patent is granted (Gallini, 2002). While legal protection is generally strong, its efficiency and effectiveness has been questioned (see for example Mansfield, 1986). The application process is typically lengthy and requires substantial resource commitments (e.g. consulting from specialized lawyers). It is therefore less attractive for smaller firms with limited resources (Byma and Leiponen, 2006). Brouwer and Kleinknecht (1999) show that the propensity to patent varies

greatly: firms engaged in R&D activities or in knowledge intensive sectors are generally more likely to patent their knowledge. This may have to do with the fact that the costs for copying an innovation are lower in certain sectors. Based on evidence from surveys of firms from Europe and the US, Arundel and Kabla (1998) show that the percentage of patented innovations varies by sector, since different sectors attribute different values to patents. Pharmaceuticals, chemicals, and machinery firms invest the most in patenting. What is more, patents provide firms with tangible representations of their R&D investments. This implies that firms may not only apply for patents because of appropriability concerns but because patents can signal the value of their otherwise intangible assets to external stakeholders (e.g. investors) (Harabi, 1995). Finally, patent protection appears to be most relevant for better-established knowledge, which can be more easily codified (as opposed to more tacit, early stage knowledge) and would otherwise be easily retrievable by many potential users (Saviotti, 1998).

Strategic appropriability strategies are built around organizational processes. They aim to prevent knowledge from spilling over or to mitigate the negative consequences of such spillovers (Harabi, 1995). Preventing spillovers is typically achieved through initial secrecy or complex design so that knowledge can only be fully exploited once it is combined with additional expertise. This adds extra barriers to knowledge transfers to competitors (see for example Szulanski, 1996). These strategies are typically applied to process innovations, which are embedded in a production system and have been found to be less frequently patented than product innovations (Harabi, 1995; Byma and Leiponen, 2006). Steps to mitigate the consequences of spillovers are usually associated with lead time or first mover advantages, which enable firms to establish competitive advantages before competitors can react (for a review see Lieberman and Montgomery, 1988). Strategic appropriability strategies do not involve a formal process. They therefore do not require dedicated investments, which makes them attractive to smaller firms (Byma and Leiponen, 2006). In contrast to formal forms of appropriability, no knowledge codification or disclosure is required. This increases the effectiveness of strategic appropriability methods because they include the protection of tacit knowledge and thwarts opportunities for competitors to 'invent around' patented innovations (Harabi, 1995; Saviotti, 1998). However, the potential of strategic appropriability strategies is also limited as important parts of the valuable knowledge are simply visible in the final product (Ndofor and Levitas, 2004). Furthermore, personnel mobility negates the effectiveness of secrecy (Arrow, 1962). Table 1 summarizes the discussion based on the literature mentioned above.

Table 1: Comparison of formal and strategic appropriability strategies

Appropriability strategy	**Formal**	**Strategic**
Major forms	Patents, copyrights, trademarks, industrial design	Secrecy, lead time, complex design
Basis of knowledge protection	Law	Prevention of spillovers
Process	Formal application to official agency	Organisation
Costs of protection	Substantial time and resource commitments	Flexible element of organizational design
Embodiment of protection	Tangible	Intangible
Type of suitable knowledge	Easy to codify, large group of potential users, low costs/high risks	All forms of knowledge

Appropriability strategy	Formal	Strategic
	of imitation, product innovations	
Limitations to effectiveness	Knowledge disclosure enables "inventing around"	Knowledge embodied in products on the markets, personnel turnover

We can infer from this discussion that the ability to achieve economic returns from knowledge related investments and, consequently, the appropriability strategy of firms and, in particular, of MNC subsidiaries may be less reflected in their number of patents than in the various appropriability methods they utilize. Table 1 shows that at the firm level a combination of legal and strategic appropriability strategies appears to be most promising, e.g. choosing secrecy to protect early stage findings and patenting inventions that are close to the market. Cassiman et al. (2002) support these complementarities between legal and strategic protection methods. Considering that knowledge transfer across national borders is a major advantage of MNCs (Kogut and Zander, 1993) and that the generation of knowledge and productivity spillovers to national firms is one of the main processes associated with this kind of firm, we expect MNCs to protect this knowledge by combining multiple forms of appropriability methods to prevent it from spilling over to host country competitors. We hypothesize:

> Hypothesis 1: Multinational subsidiaries combine more different appropriability methods than local firms.

However, MNCs have the opportunity to tailor innovation activities so that they fit into and exploit varying institutional environments across numerous host countries (Goshal and Bartlett, 1990). As stated above, they can manage the risks from outward knowledge spillovers in a particular country through internal, organizational arrangements that assign R&D responsibilities which are only valuable when connected with knowledge produced in a more protective institutional environment (Zhao, 2006). Domestic firms without foreign direct links may not have that choice. As a result, MNCs can optimize their appropriability strategies across several countries, while their local competitors cannot. Therefore, in line with the argumentation presented to support Hypothesis 1, we expect MNC subsidiaries to have clearer profiles in their appropriability strategies because they focus on highly developed appropriability methods. We propose:

> Hypothesis 2: MNC subsidiaries concentrate their appropriability strategies on a profile of highly developed methods compared to local firms.

Finally, we suggest that the choice of appropriability strategies is not independent from the host country environment. For example, the legal settings for intellectual property rights differ significantly across countries due to diversity in economic development and trade policy (Yang and Kuo, 2008). Host country factor endowments and opportunities for knowledge spillovers from local competitors have been identified as important determinants of MNCs' R&D engagements (Feinberg and Gupta, 2004). However, channels for acquiring local knowledge have to be developed over time through inter-firm and interpersonal engagements (Birkinshaw and Hood, 1998; Laursen and Salter, 2006), which generate a level of trust that facilitates knowledge flows. Reciprocity is an important driver for these knowledge flows, as

firms are more willing to share their knowledge if they can expect to receive other knowledge in return (Hakanson and Nobel, 2001). In this line of research, Cassiman and Veugelers (2002) explore the effects of knowledge flows on R&D cooperation, focussing on the distinction between incoming spillovers and appropriability. They investigate whether the ability to absorb incoming spillovers from other firms or institutions is linked to innovation activities of the firm (own R&D, for example), participation in cooperative agreements and the technological opportunities in the industry. They find that the level of knowledge of in- and outflows is not exogenous to the firm since firms can shape their incoming spillovers and appropriation capabilities through their innovation activities. In line with the works described above, we conclude that the availability of valuable inward knowledge spillovers will impact a MNC subsidiary's approach towards appropriability strategies. We derive:

> Hypothesis 3: In host country environments that offer more opportunities for knowledge sourcing, MNCs will deploy fewer and less highly developed appropriability methods.

4 Empirical study

4.1 Data

To test our hypotheses, we need to compare at least two different host country environments with different characteristics. We test our hypotheses through a harmonized survey for Portugal and Germany. Both countries are part of the European Union and use the single European currency Euro. Hence, they are comparable countries with regard to basic economic infrastructure. However, important differences remain, making the comparison between both countries a good fit for our research framework. Table 2 summarizes main indicators of economic performance and science/technology in both countries. Germany's economy is large and technology-intensive, while Portugal's economy is smaller in size and less R&D intensive. With respect to our research question, we would expect to find less restrictive appropriability strategies (Hypothesis 3) in Germany than in Portugal based on the opportunities for spillovers from the host country.

Table 2: Selected economic and technology indicators for Portugal and Germany (2006)

	Portugal	Germany
GDP at current market prices (EUR 1 000 Mio.)	147	2 247
GDP per capita at current market prices (PPS) (EU-25 = 100)	71.4	109.8
Human resources in science and technology (employees with an S&T occupation, (% of total employment)	18.6	36.9
Gross domestic expenditure on R&D (% of GDP)	0.8	2.5

Patent applications to the European Patent Office (number of applications per million inhabitants)	4.8	297.4

Source: Eurostat (2007): Europe in figures - Eurostat Yearbook 2006-07.
Most recent year available reported.

We use data from the Community Innovation Survey III (CIS III), which was undertaken by the member states of the European Union in 2001. The survey collects data on the innovation activities of firms in each country from both the manufacturing and the service sector.

The questionnaire and the methodology are based on the Oslo Manual (OECD, 1997) and harmonized across countries, allowing for comparisons between different countries. Some minor differences exist nonetheless, as countries are allowed to add questions to their questionnaire and to cover firms that are smaller than the threshold (ten employees) or belong to industries outside the core sector coverage of the CIS.

The Portuguese questionnaire is mainly a translation of the harmonized Eurostat questionnaire, but includes some additional questions. Nevertheless, and owing to the experience of CIS II, a more comprehensive design of the questionnaire was developed with several notes and examples to make it easier for the respondent to understand the questions. The German sample is stratified by region (East Germany and West Germany) in addition to size and industry to account for the effects of economic restructuring in East Germany.

To make the results of the surveys and our econometric analysis in the two countries comparable, all variables were constructed in the same way based on the harmonized survey questionnaire. Additionally, firms with fewer than ten employees were omitted from the German dataset and the NACE categories included in the German survey were brought into line with those covered in Portugal.

Since most of the questions in the survey have to be answered only by innovative firms, i.e. firms that introduced at least one product or process innovation between 1998 and 2000 or had ongoing or abandoned innovation activities, we restricted our sample to this group of firms.

The CIS captures a larger variety of innovation activities than just R&D expenditures. These include the acquisition of patents and licenses, product design, personnel training, trial production and market analysis. Innovative output includes the introduction of innovative production processes and organizational changes. It contains also a wealth of information about the organization of innovation processes, including sources of knowledge, the reasons for innovating, the perceived obstacles to innovation, the perceived strength of various appropriability mechanisms, and the resources applied to research cooperation with Universities, R&D Laboratories and other enterprises (parent, suppliers, clients, competitors, etc.). For a detailed description of the survey see Peters (2008).

Heads of R&D departments or innovation management are asked directly if and how they are able to generate innovations. This leads to the production of direct measures for

innovation processes and outputs which can complement traditional measures of innovation activity such as patents (Kaiser, 2002; Laursen and Salter, 2006). Moreover, CIS surveys are subject to extensive pre-testing and piloting in various countries, industries and firms with regard to interpretability, reliability and validity (Laursen and Salter, 2006). This multinational application of CIS surveys adds extra layers of quality management and assurance.

We complement both datasets with official statistics for overall business R&D expenditure at the industry level. For Germany this data is derived from the OECD ANBERD database, for Portugal it is provided by the Portuguese statistical office and calculated in accordance with OECD procedures.

4.2 Variables

Dependent variables

Patent applications have been considered the primary indicator for knowledge protection in large parts of the literature. However, firms patent for a variety of reasons, e.g. to deter competitors or to signal the value of their knowledge to investors (Harabi, 1995). The goal of this study is to present a more comprehensive picture of appropriability strategies. We follow Laursen and Salter (2006) and construct indices for the breadth and depth of the methods firms use to protect their knowledge. More precisely, breadth is defined as the number of different appropriability strategies applied by a firm (testing hypothesis 1). These include patents, copyrights, trademarks, industrial design, secrecy, lead time and complex design. Hence the index ranges from 0 to 7. Respondents also rate the importance of each appropriability strategy on a four point Likert scale ranging from not relevant to highly important. Again, we construct the depth index following Laursen and Salter (2006) by counting all appropriability strategies that were considered highly important (testing hypothesis 2). Like the breadth index, the depth index can also range from 0 to 7. The ranking in terms of importance is not included in the Portuguese survey, which limits cross country comparability to the breadth index alone.

Independent variables

The focal point of our analysis is the identification of differences in the breadth and depth of appropriability strategies that are specific to MNC subsidiaries. Consequently, we add a dummy variable indicating whether the survey firm is part of a multinational group with headquarters abroad. The coefficient of this variable ("foreign group") should be positive and significant in all estimations to support hypotheses 1 and 2. It should differ between Portugal and Germany to support hypothesis 3.

We add an additional variable indicating whether a firm is part of a group with domestic headquarters ("domestic group") to define the reference group of purely domestic firms more precisely. We also control for different opportunities for knowledge sourcing in different industries of the host country by adding the industry share of total R&D expenditure to the models. In addition, we control for a firms' degree of internationalization through the share of their turnover that comes from exports.

Most importantly, appropriability strategies may differ with regard to firms' innovation and knowledge production engagements. We control for major innovation inputs. The indicators we use are innovation expenditures as a share of sales, the share of employees with college education and whether the firm performs R&D activities (innovation activities/expenditures also include engagements that are directed at promoting and marketing innovations, like costs for organizing market introductions). Several studies highlight the importance of subsidiary assignments (mandates or charters) from headquarters for explaining their behavior (e.g. Birkinshaw and Fry, 1998; Birkinshaw and Hood, 1998; Hakanson and Nobel, 2001). Cantwell and Mudambi (2005) provide an in-depth discussion of subsidiary mandates, relating them back to March (1991) and the distinction between explorative (directed at new products, capabilities and markets) and exploitative innovation activities (built around and for existing capabilities and customers). We construct two indices for explorative and exploitative innovation strategies based on a question on the effects of a firm's innovation activities. Again, firms rank several items on a four point Likert scale ranging from not relevant to highly important. We add up relevant items and divide them by the maximum. Firms' innovation strategies are considered explorative based on the importance of generating new products and serving new markets. Innovation strategies are considered exploitative if quality improvements, resources and personnel cost reductions were dominant. Finally, we control for basic firm features like size (number of employees) and regional differences (location in economically challenged East Germany). We also add four industry dummies (medium high-tech manufacturing, high-tech manufacturing, distributive services and knowledge-intensive services). Low-tech manufacturing will serve as the comparison group. Appendix A shows the detailed industry classification.

4.3 Model and method

Since the dependent variable is count data in nature, the ordinary least squares regression does not deliver robust results because of over-dispersion, i.e. the observed variance is larger than the mean. Put simply, the variation in the data is not correctly reflected in the estimation. In our case, there is more variation in the data than predicted. OLS estimations would produce inefficient, inconsistent and biased results. It is therefore preferable to use models purposely designed for count data, like Poisson regressions. However, our dependent variables are non-negative count variables and reveal over-dispersion (variance > mean) violating one of the basic assumptions of the Poisson model. In addition, likelihood ratio tests reveal that Poisson models would underestimate the degree of dispersion in our sample. Over or under-dispersion can lead to biased standard errors and to erroneous p-values (Cameron and Trivendi, 1998). In this context, we apply a negative binomial regression model, which deals with over-dispersion and is frequently applied in innovation studies, in particular in studies using patent data (Hausman et al., 1984).

Negative binomial regression models account for an omitted variable bias, while simultaneously estimating heterogeneity (Cameron and Trivedi, 1998; Hausman et al, 1984). These models have Poisson-like structures but correct the over-dispersion problem by adding more variance (unobserved heterogeneity) through an additional parameter α. In other words, this parameter reflects the unobserved heterogeneity among observations avoiding the

problem of the Poisson regression model that under-fits the amount of dispersion in the outcome (Long and Freese, 2006).

More formally, the model has the following final structure:

$$\Pr(y \mid x) = \frac{\Gamma(y+\alpha^{-1})}{y!\Gamma(\alpha^{-1})}\left(\frac{\alpha^{-1}}{\alpha^{-1}+\mu}\right)^{\alpha^{-1}}\left(\frac{\mu}{\alpha^{-1}+\mu}\right)^{\alpha^{-1}}$$

Where Γ() is the gamma function (the error is assumed to follow this distribution), x is the observed variable, y is a random variable indicating the probability of observing any count of the variable, and μ is the expected count of the variable in a given period (for details of the Poisson and negative binomial regression models see Long and Freese, 2006).

We estimate three different models: breadth and depth of appropriability strategies for Germany and breadth only for Portugal because of data availability.

4.4 Descriptive statistics

Appendix B presents descriptive statistics for the Portuguese and German sample. Major features are outlined briefly in this section. There are some interesting similarities but also differences between the two samples. The average German firm is larger (300 employees) than the average Portuguese one (252 employees). 13% of firms in the Portuguese sample are subsidiaries of foreign firms, compared to 10% in Germany. The share of firms that are part of a group with domestic headquarters is higher in Germany (32%) than in Portugal (26%). However, firms in both countries generate on average the same share of sales from exports (21-22%) and invest 7% of their sales in innovation activities.

However, there are major differences in innovation activities. The share of employees with higher education is almost twice as high in Germany (23%) as in Portugal (12%) and firms perform more innovation activities directed at new products and new markets (i.e. explorative innovation) in Germany. Some of these differences can be explained by country specific industry compositions. The majority of Portuguese firms operate in low (32%) or medium tech manufacturing sectors (31%). In comparison, low tech manufacturing in Germany accounts for only 13% of the sample and the largest shares stem from medium tech manufacturing (47%) and knowledge intensive service sectors (22%).

These structural features are also apparent in firms' knowledge protection activities. Portuguese firms use typically narrower sets of appropriability strategies compared to their German counterparts. Interestingly, German firms report that on average only one appropriability strategy is highly important for protecting their knowledge (this number is not available for Portugal). We break these appropriability numbers down further and report details in Appendix C. There are stark differences in knowledge protection behavior. Only 9% of Portuguese firms patent actively while 36% of German firms do. Patents are the most widespread form of formal protection in Germany while trademarks dominate in Portugal. Lead time is the most frequent non-formal form of appropriability in both countries followed by secrecy. Then again, total numbers show strong differences. 55% of German firms use lead

time compared to just 28% in Portugal. When we compare appropriability strategies between foreign MNCs and domestic companies in both countries we find similar patterns. Foreign MNCs are more likely to engage in knowledge protection across all forms of appropriability. However, these gaps are more pronounced in Portugal than in Germany.

In conclusion, the descriptive part of our analysis highlights major differences between Portugal and Germany in innovation activities and appropriability strategies. However, these could be due to other factors like firm size or industry composition. As a result, a multivariate analysis is warranted. We find that correlations between independent variables and subsequent levels of multicollinearity are not limiting factors for our analysis (Chatterjee and Hadi, 2006). Variance inflation factors are reported in Appendix D.

5 Results

In this section, we first analyze the determinants of appropriability depth in innovative firms. A special focus is put on firms that are part of a foreign group. As mentioned above, the Portuguese database does not include information on the importance attributed by firms to the different appropriability strategies, so this scrutiny is only made for Germany. Following this analysis, we will compare results for the determinants of appropriability breadth in Portugal and Germany. Finally, we will interpret the results, taking into consideration the hypotheses drawn above. Table 3 presents the results.

Table 3: Estimation results of negative binomial models for Portugal and Germany

	Germany		***Portugal***
Variable	***Approp. Depth***	***Approp. Breadth***	***Approp. Breadth***
MNC with HQ abroad (d)	0.23**	0.05	0.26*
	(0.11)	(0.08)	(0.15)
Domestic group (d)	0.16**	0.10**	-0.08
	(0.08)	(0.05)	(0.13)
Industry share of nat. R&D expend. (ratio)	0.73	-0.04	-0.74
	(0.62)	(0.44)	(1.62)
Exports as a share of sales (ratio)	0.33**	0.43***	-0.01
	(0.14)	(0.10)	(0.16)
Share of empl. With college educ. (ratio)	0.62***	0.55***	0.78**
	(0.18)	(0.13)	(0.39)
R&D activities (d)	0.88***	0.80***	0.40***
	(0.12)	(0.08)	(0.11)
Innovation exp. as a share of sales (ratio)	1.18***	0.91***	-0.21
	(0.26)	(0.18)	(0.30)
Explorative innovation strategy (index)	0.95***	0.43***	0.89***
	(0.14)	(0.09)	(0.17)
Exploitative innovation strategy (index)	0.22	0.18*	0.23
	(0.14)	(0.10)	(0.19)
No of employees (log)	0.10***	0.11***	0.17***
	(0.03)	(0.02)	(0.04)
Location in East Germany (d)	-0.16**	-0.25***	
	(0.08)	(0.05)	
Medium tech manufacturing (d)	0.16	0.22**	-0.10
	(0.12)	(0.08)	(0.12)
High tech manufacturing (d)	0.23	0.26**	0.03

Variable	*Germany*		*Portugal*
	Approp. Depth	*Approp. Breadth*	*Approp. Breadth*
	(0.15)	(0.11)	(0.22)
Distributive services (d)	0.26	0.19*	-0.52***
	(0.16)	(0.11)	(0.18)
Knowledge intensive services (d)	-0.06	0.07	-0.07
	(0.16)	(0.11)	(0.20)
Constant	-2.38***	-1.23***	-1.54***
	(0.22)	(0.14)	(0.23)
Ln alpha	-2.60***	-1.46***	-0.41***
	(0.35)	(0.24)	(0.16)
Pseudo R2	0.09	0.10	0.06
N	1083	1083	751
LR/Wald chi2	298.54	428.03	103.36
P-value	0.00	0.00	0.00

Standard errors in parentheses. Significance levels: * p<0.10, ** p<0.05, *** p<0.01.

The first column of Table 3 shows the results on appropriability depth for Germany. Firms that are part of a group have a more targeted set of appropriability strategies than firms that are not part of a formal network. Comparing the coefficients of the dummy variables for foreign and national groups, foreign MNCs have a greater depth than firms belonging to domestic groups.

The export share also has a positive influence on the appropriability depth of German firms. All variables that measure innovation and knowledge production engagements (share of employees with college education, engagement in R&D activities and innovation intensity), are positively related to the dependent variable, indicating that firms with a larger output of new knowledge need to make more protection efforts despite also having more experience of how to protect it.

When it comes to firms' innovation strategies, the explorative innovation variable has a positive and significant impact on appropriability depth while the exploitative innovation variable is not significant. Firms with innovation strategies directed at new products, capabilities and markets have both broader and deeper appropriation methods. Innovation activities built around existing capabilities and customers do not influence the value attributed by firms to the protection methods.

Firm size (number of employees) has a positive effect, while location in East Germany shows a negative one. Finally, the industry dummies and the industry share of national R&D expenditure are not significant, showing that there are no industry level effects with regard to appropriability depth.

Columns 2 and 3 of Table 3 present the results obtained when running the model with appropriation breadth as the dependent variable using the German and the Portuguese data, respectively. Our key variable, whether a firm is part of a multinational group with headquarters abroad, shows different results for the two countries. A positive effect for Portugal contrasts with an insignificant one for Germany. In addition, some differences exist between the two countries with respect to other independent variables. The results for Germany are similar to the ones obtained for appropriability depth, only differing with regard to the significance of the exploitative innovation strategy variable and on industry dummies.

All other determinants that explain the importance attributed to the different appropriability strategies are similar to the ones that explain appropriability depth. For Portugal, the variables national group, share of exports and innovation intensity are not significant. The exports share result can be explained mainly by a country specific factor: Portugal's exports are relatively low-tech, providing fewer opportunities to create knowledge that would then require protection.

In conclusion, we find interesting distinctions between the results for Portugal and Germany. MNCs in Germany do not choose a wider range of appropriability methods compared to local firms but they choose a clear profile of highly developed ones. It is important to highlight the advantages of the cross-country comparison. An investigation focussing solely on the German context would have concluded that this clear profile is important for MNCs, while broad appropriability approaches are not. Contrasting these findings with the Portuguese context (based on a harmonized dataset) reveals that this is not generally the case. The foreign group dummy variable is significant for breadth in Portugal but not in Germany. Hence, MNC appropriability strategies are less restrictive in host country environments with more opportunities for knowledge sourcing such as Germany (hypothesis 3).

Additionally, we identify a noteworthy trend in the results of the control variables. We did not develop no a priori hypotheses for these variables. Higher degrees of internationalization (being part of a multinational group with domestic headquarters as well as higher export shares) are associated with more breadth and depth of appropriability strategies in Germany but not in Portugal. We cannot draw any conclusions on the direction of causality based on our estimations. However, the inclusion of appropriability strategies in the discussion on whether firms "learn from exports" or "learn for exports," i.e. are more productive in the first place (for a review see Keller, 2004), appears to be a fruitful path for further research.

6 Conclusions

Our research investigates MNC appropriability strategies including not only formal methods (patents, copyrights, trademarks) but also strategic ones (secrecy, lead time, complex design). We conceptualize a firm's breadth and depth of knowledge protection strategies and the special challenges and opportunities for MNC subsidiaries. Moreover, we argue that these approaches differ with regard to host country challenges and opportunities.

Two main conclusions can be drawn from our results based on empirical tests that were put forward using the harmonized databases for Germany and Portugal. Firstly, MNC subsidiaries have more deep and diversified appropriability strategies that go beyond patents. Secondly, MNC appropriability strategies are less restrictive in host country environments with more opportunities for knowledge sourcing. The latter result only came to light thanks to our cross country study based on a harmonized survey. Interpretations based on only one host country (Germany) would have been misleading.

Our findings extend existing research, which has found that opportunities for host country knowledge spillovers are an important driver for MNC engagements (e.g. Almeida and Phene, 2004). We are able to show that this is not only reflected in MNC location choices but also in the way in which they protect their knowledge. Multinationals seem to come to countries with more opportunities for knowledge sourcing, such as Germany, to capture knowledge spillovers. We suspect that they opt for less restrictive appropriability strategies in order to facilitate host country knowledge exchanges by demonstrating reciprocity. In Portugal, a country with fewer opportunities for knowledge sourcing, subsidiaries of multinationals seem to be more focused on preventing their knowledge from spilling over to local firms, since they have fewer opportunities to receive valuable knowledge in exchange.

Another aspect that differentiates these two countries is that the internationalization of domestic firms is associated with a larger breadth and depth of appropriability strategies in Germany but not in Portugal. This result may be explained by the level of technology intensity of the main exporting sectors in each country. More traditional and low tech sectors in Portugal tend to produce less knowledge that can spill over to other firms, while opportunities in Germany predominantly stem from high-tech sectors which have more knowledge to protect. We treat these variables as control variables without developing a priori hypotheses but these trends may provide valuable paths for research projects.

Our findings provide opportunities to derive both management and policy recommendations. On the management side, we find evidence that firms need to develop appropriability strategies that are not limited to formal methods like patenting. This seems to be especially relevant if they expand their activities to other countries, i.e. turn multinational. Then again, a "zero spillover" approach that limits all knowledge flows has its downside in host countries where firms hope to benefit from knowledge spillovers. MNCs cannot expect commitments from host country institutions for knowledge sharing if they do not share themselves. This line of reasoning provides a link to the derivation of policy recommendations. Federal and regional governments have invested heavily into attracting MNC engagements in recent years but the measurable effects on efficiency and productivity spillovers have been mixed (Keller, 2004). Our findings suggest that MNC play a much more active role not only in sharing but also in protecting their knowledge than previous studies, based on patent statistics and limited to a single (often highly developed) host country, have been able to show. In that sense, governments should not limit the goals of their financial support to attracting MNCs. Instead, incentive schemes should become part of policy proposals that propel MNC subsidiaries to engage in local knowledge flows and become fully embedded.

Future research should complement this study. In line with Arundel and Kabla (1998), one possible line of development could be deepening the analysis of the different types of appropriability. This should cover formal methods (patents, copyrights, trademarks) and strategic methods (secrecy, lead time, complex design), trying to scrutinise whether MNC located in Portugal and Germany choose similar or different types of strategies to protect their knowledge. In addition, comparisons with other countries, especially in the developing world, could provide further insight into the mechanisms behind MNCs' appropriability strategies.

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Appendices

Appendix A: Industry breakdown

Low-tech manufacturing	NACE 15-22, 36, 37
Medium-tech manufacturing	NACE 23, 24(excl.244), 25-29, 31, 34, 35(excl.353)
Hi-tech manufacturing	NACE 244, 30, 32, 33, 353
Low knowledge-intensive services	NACE 51, 60, 63
Knowledge-intensive services	NACE 61, 62, 64, 65, 66, 67, 72, 73, 74.2, 74.3

Appendix B: Descriptive statistics: Dataset

Variable	***Portugal***		***Germany***	
	Mean	*SD*	*Mean*	*SD*
Breadth of appropriability strategies	1.18	1.52	2.24	1.93
Depth of appropriability strategies	-	-	1.19	1.39
Foreign group (d)	0.13	0.34	0.10	0.30
Domestic group (d)	0.26	0.44	0.32	0.47
Industry share of nat. R&D expend. (ratio)	0.03	0.04	0.04	0.06
Exports as share of sales (ratio)	0.22	0.32	0.21	0.25
Share of empl. with college educ. (ratio)	0.12	0.16	0.23	0.24
R&D activities (d)	0.65	0.48	0.78	0.41
Innovation spend. as share of sales (ratio)	0.07	0.27	0.07	0.12
Explorative innovation strategy (index)	0.53	0.32	0.65	0.28
Exploitative innovation strategy (index)	0.49	0.25	0.49	0.26
No of employees	252.40	962.05	299.84	638.27
No of employees (log)	4.40	1.33	4.66	1.41
Location in East Germany (d)	-	-	0.35	0.48
Low tech manufacturing (d)	0.32	0.47	0.13	0.34
Medium tech manufacturing (d)	0.31	0.46	0.47	0.50
High tech manufacturing (d)	0.05	0.22	0.08	0.28
Distributive services (d)	0.13	0.34	0.10	0.30
Knowledge intensive services (d)	0.18	0.38	0.22	0.41
No of observations	747		1,083	

Appendix C: Descriptive statistics: Share of firms with appropriability strategy

	Portugal	***Germany***	***Portugal***		***Germany***	
			Domestic	*Foreign group*	*Domestic*	*Foreign group*
Patent	9%	36%	8%	17%	35%	48%
Design pattern	7%	27%	5%	19%	26%	29%
Trademark	25%	26%	22%	44%	25%	34%
Copyright	4%	9%	3%	11%	9%	9%
Secrecy	22%	47%	22%	27%	46%	53%
Complex design	14%	25%	13%	23%	25%	27%
Lead time	28%	55%	28%	32%	54%	59%

Appendix D: Variance Inflation Factors (VIF)

Variable	*Portugal*	*Germany*
Foreign group (d)	1.30	1.21
Domestic group (d)	1.45	1.25
Industry share of nat. R&Dexpend. (ratio)	1.67	1.35
Export share of sales (ratio)	1.28	1.39
Share of empl. with college educ. (ratio)	1.83	1.93
R&D activities (d)	1.20	1.27
Innovation expend. as share of sales (ratio)	1.07	1.19
Explorative innovation strategy (index)	1.23	1.23
Exploitative innovation strategy (index)	1.12	1.24
No of employees (log)	1.53	1.57
Location in East Germany (d)	-	1.16
Medium tech manufacturing (d)	1.50	2.95
High tech manufacturing (d)	1.37	1.80
Distributive services (d)	1.37	1.67
Knowledge intensive services (d)	2.83	3.12
Mean VIF	1.46	1.62

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