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R&D Co-operation in European Post-transition Economies

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Abstract

Innovation systems abroad become more and more important to multinational enterprises (MNEs) as sources of knowledge and technology. On the other hand, MNEs' foreign subsidiaries can be considered agents of technological and economic development in their target location region. Applying a logit estimation, this discussion paper investigates which firm- and region-specific determinants influence co-operations in the area of research and development (R&D) between the foreign subsidiary and the regional innovation system. Results suggest that especially the foreign subsidiary's mandate in terms of R&D and management, its size and the regional knowledge stock are positively associated with these co-operations. The analysis focuses on post-transition economies, using the example of five selected CEE countries and East Germany. We exploit a unique dataset – the *IWH FDI Micro Database* – which holds information on 1,245 foreign subsidiaries in this region.

Keywords: foreign direct investment, Central East Europe, East Germany, R&D-cooperations

JEL Classification: F23, O30, P13, P20

FuE-Kooperationen in europäischen Post-Transformationsökonomien

Zusammenfassung

Ausländische Innovationssysteme werden als Quelle für Wissen und Technologie für multinationale Unternehmen (MNU) immer wichtiger. Andererseits fungieren die Tochterunternehmen von MNU als Treiber der technologischen und wirtschaftlichen Entwicklung in der Zielregion. Unter Anwendung eines Logit-Schätzverfahrens wird in diesem Diskussionspapier untersucht, welche firmenspezifischen und regionalen Determinanten Kooperationen im Bereich Forschung und Entwicklung (FuE) zwischen dem ausländischen Tochterunternehmen und dem regionalen Innovationssystem beeinflussen. Die Ergebnisse legen nahe, dass vor allem die Eigenständigkeit des Tochterunternehmens im Bereich FuE und Management, seine Größe und die regionale Wissensbasis positiv auf diese Kooperationen wirken. Die Untersuchung fokussiert dabei auch Post-Transformationsregionen am Beispiel von fünf ausgewählten MOE-Ländern und Ostdeutschland. Wir verwenden einen großen Datensatz – die *IWH- FDI-Mikrodatenbank* –, der Informationen über 1 245 ausländische Tochterunternehmen in dieser Region enthält.

Schlagwörter: Ausländische Direktinvestitionen, Mittel- und Osteuropa, Ostdeutschland, FuE-Kooperationen

JEL-Klassifikation: F23, O30, P13, P20

1 Introduction

The technology accumulation approach towards firms' internationalization suggests that foreign affiliates have an important role in the generation and diffusion of new technologies in the multinational firm (Cantwell 1989 or Cantwell 1995). From an empirical perspective, we know that the majority of multinational enterprises' (MNEs) technological activities is still concentrated in their home countries. There is evidence, however, that important strategic activities such as research and development (R&D) are increasingly organized in geographically dispersed centres and open networks in domestic or foreign locations (Narula and Guimón 2010; Patel and Vega 1999; Le Bas and Sierra 2002; Narula and Zanfei 2005). This allows MNEs to tap into location-specific advantages and enhance the enterprises competitiveness (Dunning 1977, D'Agostino and Santangelo 2012). Due to this development foreign innovation sytems become more and more important to MNEs as sources of knowledge and technology (Meyer, Mudambi, and Narula 2011). On the other hand, this increases productivity and industrial upgrading in the location region, where foreign subsidiaries can be considered agents of technological and economic development (Günther and Gebhardt 2005). The evolutionary perspective on technology development (Kim and Nelson 2000) suggests that technology transfer from developed to developing economies is based on technological linkages between the foreign subsidiary and the regional environment. Empirical studies on developed countries support this assumption (Gentile-Lüdecke and Giroud 2012).

The aim of this paper is to contribute to the literature by investigating the determinants of technological linkages between MNEs' foreign subsidiaries and the regional innovation system, thereby leading to a better unterstanding which firm- and region-specific factors influence the regional co-operation behaviour in the area of R&D. Traditionally, research in technological activities of MNEs' foreign subsidiaries is concentrated on advanced economies. However, the institutional and economic changes in Central and Eastern Europe (CEE) and East Germany call for an investigation of the patterns of MNEs' technological co-operation behaviour in this particular region. Even though the post-transition phase is no longer characterized by institutional change, there are still functional weaknesses and economic differences which arise directly from the former political and economic system and the transition period itself (*Transition Report* 2009).

Recent research shows that MNEs' investment into European transition economies is dominated by market- and efficiency seeking motives; the search for knowledge is still of secondary importance, but has essentially gained importance over time (Gauselmann, Knell, and Stephan 2011). Foreign and domestic technological activities - such as R&D, innovation, and the exchange of knowledge and technology - are an important factors in the catching-up process of transition countries towards knowledge-based economies, which provide a basis for long-term sustainable economic growth (Fu, Pietrobelli, and Soete 2010; Perugini, Pompei, and Signorelli 2008). This paper offers an analysis of an unique dataset on 1.245 foreign subsidiaries based in Poland, Hungary, the Czech Republic, Slovakia, Romania and East Germany.

So far, literature has focused mainly on two aspects of technological linkages. One strand of literature is concerned with the impact of R&D co-operation on firm performance (Cassiman, Veugelers, and Zuniga 2010, Belderbos, Carree, and Lokshin 2004; Yamin and Otto 2004; Almeida and Phene 2004) and finds a positive impact on productivity and innovation. For example Belderbos, Carree, and Lokshin (2004) find for Dutch firms that R&D co-operation with competitors and suppliers improve the firm performance and that customers and universities seem to be important sources of knowledge. Almeida and Phene (2004) examine the influence of external knowledge on innovation in subsidiaries in the U.S. semiconductor industry and find a positive impact of R&D linkages to host country firms on innovation as does Cassiman, Veugelers, and Zuniga (2010) for Belgian firms.

Another strand of literature deals with linkages between multinational and different kinds of domestic partners in less developed economies (Giroud, Jindra, and Marek 2012; Gentile-Lüdecke and Giroud 2012; Jindra, Giroud, and Scott-Kennel 2009; Günther, Stephan, and Jindra 2008; Günther, Jindra, and Stephan 2009 Santangelo 2009). Gentile-Lüdecke and Giroud (2012) rely on firm-level survey data and focus on knowledge transfers from foreign subsidiaries to suppliers of the Polish automotive sector. They also find a high impact of the foreign subsidiary's mandate influences knowledge transfer, especially to domestic suppliers. Giroud, Jindra, and Marek (2012) interpret further survey data on foreign subsidiaries in transition economies and investigate linkages between foreign subsidiaries and domestic suppliers and again find the foreign subsidiary's autonomy over technology-related business functions and technological embeddedness to be positively associated with knowledge transfer via supplier linkages. Jindra, Giroud, and Scott-Kennel (2009) focus on linkages between

foreign subsidiaries and domestic suppliers and customers using survey evidence on foreign subsidiaries in the CEE region and discuss the nature of subsidiary roles. Their results show that the extent of technology transfer via supplier linkages is highly related to the foreign subsidiary's strategic mandate.

Santangelo (2009) focuses on local linkage creation in a periphal region in Italy. She adds information on knowledge-sourcing mandate of the foreign subsidiary to her investigation and finds empirical evidence that linkages are more likely if the MNE enters the market with a competence-creating strategy. She distinguishes between linkages with local suppliers, customers and research institutions as do Günther, Stephan, and Jindra (2008), who focus on survey evidence on foreign subsidiaries' technology and knowledge sourcing in East Germany and find, too, that a competence-augmenting strategy increases the likelihood for linkages. Additionally, they find that regional factors are associated with MNE's technology and knowledge sourcing, depending on the kind of knowledge sources (suppliers, customers or scientific institutions).

The article adds to the literature in several ways: first, it focuses on determinants of *R&D co-operations* between foreign subsidiaries and domestic firms, that is suppliers, customers, and research institutions. Second, it focuses on the underestimated region of *post-transition* economies. We argue that the process of catching-up in post-transition regions can only be supported if a technological interaction between MNEs' subsidiaries and regional innovation system succeeds. Third, it exploits firm-level data from a unique and very large dataset, the *IWH FDI Micro database*. And fourth, it connects the analysis of these firm-specific determinants with *regional (NUTS 2) location factors*. MNE strategies in the CEE countries have been content of former analyses. However, no cross-country research has yet combined the analysis of firm-level with regional determinants to find out more about the technological co-operation behaviour of foreign subsidiaries. This is an advantage of the analysis as research on economic geography has emphazised the importance of the sub-national level when examining technological capabilities.

The paper is structured as follows: in section 2 we give a short overview of the theoretical background and derive hypotheses. In section 3 we introduce the data. Section 4 contains the estimation model and empirical results. In section 5 we discuss and interpret the empirical regression results. Section 6 contains the annex.

2 Theoretical background and hypotheses

Cantwell's technology accumulation theory explains the internationalisation of enterprises emphasising the capability increase within an MNE (Cantwell 1989). Within this line of thought, the accumulation of technology means an economic advantage for the MNE (Cantwell and Piscitello 2000), including both the acquisition of new skills and the generation of new technologies (Cantwell 1989; Cantwell 1995; Cantwell 2000). Cantwell (Cantwell 1989; Cantwell 1995) argues that successfull MNEs, on the one hand, generate spillover effects to the location of investment, increasing knowledge. On the other hand, they benefit from the technological environment which develops at the affiliates' location (Cantwell and Iammarino 1998, Cantwell and Iammarino 2001, Cantwell and Iammarino 2003). Cantwell and others (see e.g. Cantwell 1989 or Kogut and Chang 1991; Grant and Baden-Fuller 2004) argue that the investment in foreign R&D is also motivated by the desire to improve the MNE's access to technology and augment the MNE's economic advantage by benefitting from the foreign location's technological environment. Cantwell's theoretic approach is therefore founded on the assumption that technological activities are location- as well as firm-specific (Cantwell 1989; Cantwell 1995).

Hence, this paper tests for firm-specific as well as regional determinants influencing the external technological linkages between foreign subsidiaries and host economy. Technological linkages may serve different purposes depending on the type of partner, however. Co-operation with customers may mainly aim at risk reduction connected with the introduction of new products and ensure market expansion while co-operation with suppliers is often motivated by costs reductions. Co-operation with universities and reserach institutions is usually aimed at the search for knowledge and innovations (Berlderbos, Carree, and Lokshin 2006). Hence, this paper tests for differences in the technological co-operation behaviour with customers, suppliers, and research institutions in the region of investment.

As already mentioned, there is an increasing consensus in literature that linkages to customers, suppliers and research institutions are essential for the accumulation of knowledge in MNEs and MNE subsidiaries (Filippov and Duysters 2011). Thus, the evolution of subsidiaries is part of the MNE's global corporate strategy and the subsidiaries' decision which knowledge resources to access is influenced by the operational mandate within the MNE (Almeida and Phene 2004; Liu 2010

or Santangelo 2009). And following Cantwell (Cantwell and Mudambi 2000) or Frost et al. (Frost, Birkinshaw, and Ensign 2002; see also Grant 1996), the competence-creating and knowledge-accumulation of the foreign subsidiary depends considerably on the extent of decision-making authority in the subsidiary. This might as well apply for foreign subsidiaries' technological linkages.

Therefore, we hypothezise:

H1a: The foreign subsidiary's mandate in terms of R&D functions is positively associated with R&D co-operations with the regional innovation system.

H1b: The foreign subsidiary's mandate in terms of management functions is positively associated with R&D co-operations with the regional innovation system.

In the context of the resource-based view of the firm, according to which the exploitation of internal and external resources is crucial for the firm's economic performance (see f.e. Peteraf 1993), it has been argued that it is more difficult for small firms to cooperate due to comparatively few human and financial resources (Lu and Beamish 2006). Furthermore, new institutional economics point out that is more likely for larger firms to overcome cost barriers, information asymmetries or the adverse selection risk and find adequate co-operation partners (Spence 1976; Kudic, Pyka, and Guenther 2012).

Applying these assumptions on R&D co-operation behaviour, we formulate our second hypothesis:

H2: The size of the foreign subsidiary is positively associated with R&D co-operations with the regional innovation system.

Furthermore, Cantwell and others argue that co-operation behaviour is related to strategic entry motivations (Kuemmerle 1997; Cantwell and Mudambi 2005; Dunning and Lundan 2008). They suggest that the subsidiary's competence-seeking mandate increases linkages with the domestic economy (Cantwell and Mudambi 2000).

This leads us to hypothesis 3:

H3a: A knowledge- and technology-seeking investment motive of the MNE is positively associated with R&D co-operations with the regional innovation system.

Frost (2001) states a technology-seeking investment motive can be attended by a more autonomous set of activities in the foreign subsidiary. In such cases, the foreign subsidiary's technological linkages are more likely.

Thus, we hypothize that these two determiants have an additional explanatory power:

H3b: A knowledge-seeking investment motive of the MNE in conjunction with the subsidiary's mandate in terms of R&D function is positively associated with R&D co-operations with the regional innovation system.

As mentioned above, we follow Cantwell (Cantwell 1989; Cantwell 1995) and argue, that in addition to these firm-specific factors, the region's endowment influences the probability of technological linkages between the foreign subsidiary and the regional innovation system. Also the resource-dependent view suggests that the subsidiary's behaviour and capability are among others influenced by host country location-specific advantages (Doerrenbaecher and Gammelgaard 2006; Jindra, Giroud, and Scott-Kennel 2009). We argue that these regional determinants are location-bound and cannot be adopted by the MNE's headquarter. To understand geographically bound knowledge, Jacobs (Jacobs 1969; Audretsch and Feldman 2004) states that geographic proximity matters in transmitting knowledge. This assumption motivates the MNE's decision to establish a foreign subsidiary. Feldman (Feldman 1994a; Feldman 1994b) explains the interaction between the foreign subsidiary and the domestic economy with a diminishment of firms' uncertainty of technological activity. In addition, he argues that there have to be exploitable resources at the foreign subsidiary's location.[1] Literature on R&D internationalization has documented that highly innovative regions attract more technology-seeking foreign R&D (Cantwell and Mudambi 2005; Dunning and Narula 1995; Kuemmerle 1999; D'Agostino and Santangelo 2012). Furthermore, the location's endowment with knowledge sources seems to be a key factor of the subsidiary's knowledge-seeking (Filippov and Duysters 2011). In terms of R&D linkages that means that technological dynamic regions are more likely to foster knowledge exchange between foreign subsidiary and host economy. Thus, we hypothezise:

H4a: The technological endowment in the region of investment is positively associated with R&D co-operations with the regional innovation system.

[1] There are other concepts of proximity that play a role in the creation of technological linkages, like organizational, social or institutional proximity which are not considered here (Boschma 2005).

H4b: The regional knowledge stock in the region of investment is positively associated with R&D co-operations with the regional innovation system.

3 The *IWH FDI Micro database*

The analysis is based on a unique dataset, the *IWH FDI Micro database*. It contains the assessment of management personnel of foreign invested firms on relevant determinants of locational factors, the organisation of R&D and innovation in the subsidiaries, as well as the potential for knowledge spillovers to and from the host economy.

The data results from field work in 2009 and includes information on foreign subsidiaries in Hungary, Poland, Romania, Slovakia, the Czech Republic and East Germany. These countries were chosen based on the intent to cover a country sample which reflects preferably different socio-political and economic stages of the transition process. Hungary and Poland as big countries where economic convergence is rather advanced and which have been rather successful in attracting and embedding value-adding FDI. The Czech Republic and Slovakia as small countries on a similar stage in the transition process, Romania as a country which is somewhat still in transition and East Germany which is a case of its own, because of the massive financial support it received from the western part of the country after reunification (Gauselmann and Marek 2012; Narula and Guimón 2010; Filippov and Duysters 2011). A 'foreign owned firm' is defined as a legally independent enterprise with a foreign equity participation of at least 10 per cent and/or an ultimate owner located abroad.

The East German subsample of foreign investors is supplemented by information on West German multinational investors, since West German investment playes a crucial role in the transition process in East Germany.[2]

Table 2 in the annex gives an overview of variables, their sources, and expected impact on the dependent variable.

[2] See Günther, Gauselmann, et al. 2011 for more detailed information. See also IWH Data and Methods homepage http://www.iwh-halle.de/projects/2010/fdi/d/DatenundMethoden.asp

3.1 Country composition

The database contains data from 1.245 firms with inward FDI (185 from the Czech Republic, 57 from Hungary, 216 from Poland, 128 from Romania, 30 from Slovakia, and 629 from East Germany), with 295,424 employees.[3] The total data set contains 617 (49,5%) foreign subsidiaries in the manufacturing sector (NACE 14-41) and 628 (50,5%) in selected services (NACE 51-74 & 90-93). Not all firms provided information on all questions, hence the database is unbalanced.[4]

Table 1: The *IWH FDI Micro database*: Country Composition

	No. of subsidiaries	In %	Employment	In %
East Germany	629	50.5	96,317	32.6
CEE Countries	616	49.5	199,107	67.4
Czech Republic	185	14.9	33,687	11.4
Hungary	57	4.6	15,122	5.1
Poland	216	17.3	93,974	31.8
Romania	128	10.3	39,563	13.4
Slovakia	30	2.4	16,716	5.7
Total	**1,245**	**100**	**295,424**	**100**

3.2 Representativeness

We used chi2 tests to check for representativeness of the samples for East Germany and the CEE countries in comparison with the respective basic population. [5]

Regarding the sample of multinational investors in East Germany, we find a distribution that does not differ significantly from the underlying population with regard to sectors (industry vs selected services). However, we find significant differences for the regional (NUTS-2 level) distribution and subsidiaries' size. The regional sample deviation is mainly driven by the strong underrepresentation of enterprises located in Berlin. It is worthwhile pointing out, that the regional distribution was not part of the sample stratification. Furthermore, there is an underrepresentation in the sample of subsidiaries with more than 250 employees.

[3] In the East German sample very small subsidiaries (1-10 employees) were included, due to the very fragmented structure of the East German economy.

[4] See Günther, Gauselmann, et al. 2011 for more detailed information.

[5] The total population of the *IWH FDI Microdatabase* was drawn from Bureau van Dijks MARKUS and AMADEUS databases.

For the CEE sample we find significant differences in the distribution across the five countries due to underrepresentation of Czech and Polish subsidiaries and corresponding overrepresentation of Hungarian, Slovakian and Romanian subsidiaries. For each individual country sample we find no significant deviation in the regional (NUTS-2 level) or sectoral distribution and subsidiaries' size between basic population and sample [6].

In general, the results suggest that the basic population and its corresponding samples generate a reliable data set.

3.3 Descriptives

R&D co-operation between foreign subsidiaries and partners in the region of invetsment is significantly more frequent in East Germany than in the selected CEE countries and that R&D co-operation between foreign subsidiaries and regional partners is significantly more frequent in the manufacturing branch than in selected services. In the manufacturing sector most R&D co-operations are realsized by foreign subsidiaries belonging to NACE 24, 25, 28, and 29. In the service sector most R&D co-operations are realized by foreign subsidiaries belonging to NACE 51, 72, and 74.

A majority of foreign subsidiaries cooperate with regional research institutions which do 76.6% of foreign subsidiaries in East Germany and 65.4% of foreign subsidiaries in the selected CEE countries. R&D co-operation with regional suppliers is second important with 37.7% of foreign subsidiaries in East Germany and 41.5% in the selected CEE countries. Finally, 34.7% of foreign subsidiaries in East Germany maintain R&D co-operation with regional customers and 27.7% of foreign subsidiaries in the selected CEE countries. Regarding the sectoral division of the sample, descriptive analyses show that the distribution between industry and selected services range from 45-55% in East Germany and the Czech Republic with less industry in both cases. It ranges also between 45 and 55% in Hungary, Poland and Slovakia with a predominance of industry, however. In Romania, we have the widest range with 67% of the foreign subsidiaries belonging to the industry sector and 33% to the servive sector.

[6] see also Representativeness, Survey 2009 and Methodological Note, Survey 2009, http://www.iwh-halle.de/projects/2010/fdi/d/DatenundMethoden.asp for more detailled information

4 Empirical analysis

Information on 52 NUTS-2 regions from Eurostat and the European Patent Office (EPO) on the regional technological endowment and the regional knowledge stock was added to the *IWH FDI Micro database*. Other determinants, like e.g. information on R&D activity, industry or agglomeration was not added to the analysis due to data restriction on the regional level, especially for the CEE countries.

On the firm level we decided not to include information on the innovative activities of the foreign subsidiary, because former studies have come to ambiguous results on the issue whether the causality runs from the foreign subsidiary's technological activities to technological co-operation or vice versa (see f.e. Frost 2001 or Yamin and Otto 2004; Günther, Stephan, and Jindra 2008).

Table 3 in the annex lists the 52 NUTS-2 regions included in the analysis.

4.1 Estimation Approach

The measure for the foreign subsidiaries's regional knowledge and technology linkages is based on the information whether the foreign subsidiary did cooperate in the area of R&D with the regional innovation system or not. The relation between the dependent variable and the independent variables can be indicated as

$$\mathbf{y} = \mathbf{X}\boldsymbol{\beta} + \boldsymbol{\epsilon}. \tag{1}$$

In equation (1) $\mathbf{y}$ is a Ix1-vector describing the observed R&D co-operation of the foreign subsidiaries with the regional innovation system with (i=1,...,I) where i is the number of foreign subsidiaries. The IxN-matrix $\mathbf{X}$ indicates individual characteristics of the independent variables with the number of foreign subsidiaries (i=1,...,I) and the number of observed individual characteristics (n=1,...,N). The Nx1-vector $\boldsymbol{\beta}$ is the coefficients' vector and the vector $\boldsymbol{\epsilon}$ is individual error term, which includes all unobservable factors.

Referring to a single observation this can be noted as:

$$y_i = \mathbf{x_i'}\boldsymbol{\beta} + \epsilon_i. \tag{2}$$

The actual and observable R&D co-operation between foreign subsidiary and regional innovation system results from the firm's cost-benefit analysis and is generally described with the random utility function, where two choices are provided (see Greene 2003).

These two choices are denoted U^1 and U^0, with U^1 indicating R&D co-operation between foreign subsidiary and regional innovation system and U^0 indicating no R&D cooperation between foreign subsidiary and regional innovation system. The observed choice between the two reveals which one provides the greater utility, though not the unobservable utilities themselves.

Hence, the observed indicator R&D co-operation between foreign subsidiary and regional innovation system equals 1 if $U^1 > U^0$ and 0 if $U^1 \leq \mathrm{U}^0$. A common formulation of this relation is the linear random utility model,

$$\mathbf{U}^1 = \mathbf{x}'\boldsymbol{\beta_1} + \epsilon_1 \tag{3}$$

and

$$\mathbf{U}^0 = \mathbf{x}'\boldsymbol{\beta_0} + \epsilon_0. \tag{4}$$

The probability of R&D co-operation between foreign subsidiaries and regional innovation system, Y=1, can be interpreted as $Prob[U^1 > U^0]$. Then, if we denote by Y=1 the foreign subsidiary's choice to cooperate with the regional innovation system in the area of R&D, we have

$$Prob[Y = 1|\mathbf{x}] = Prob[U^1 > U^0] = Prob[\mathbf{x}'\boldsymbol{\beta} + \epsilon > 0|\mathbf{x}] \tag{5}$$

Following Greene (2003), we use a logit model for the estimation which is characterized by the equation

$$Prob(Y = 1|x) = \frac{e^{x\prime\beta}}{1 + e^{x\prime\beta}} \tag{6}$$

This leads us to the estimation design and the empirical results of the logit estimation.

4.2 Estimation design and empirical results

In table 4 on page 22 the results of the logit estimation for the whole data set are shown (columns 4 and 5). Here, foriegn subsidiaries can have one or more different types of R&D co-operation partners. The first three columns of table 4 contain the regression results for each group of explanatory variables. Columns 6-8 contain the regression estimates for the subsamples on R&D co-operation with each single kind of partner: regional suppliers, regional customers and regional research institutions.

The dependent variables:

- *Foreign subsidiary's regional knowledge and technology linkages*:

  For the whole sample, the dependent variable is 1 if the foreign subsidiary cooperated in the area of R&D with the regional innovations system. The dependent variable takes 0 for all other foreign subsidiaries.

  For the suppliers sub-sample it is 1 if the foreign subsidiary cooperated in the area of R&D with the regional suppliers not part of its own enterprise group. The dependent variable takes 0 for all other foreign subsidiaries.

  For the customers sub-sample it is 1 if the foreign subsidiary cooperated in the area of R&D with the regional customers not part of its own enterprise group. The dependent variable takes 0 for all other foreign subsidiaries.

  For the reserach institutions sub-sample it is 1 if the foreign subsidiary cooperated in the area of R&D with the regional research institutions. The dependent variable takes 0 for all other foreign subsidiaries.

This design allows to keep the sample size as large as possible. Neither information on the total number of R&D co-operations nor information on the number of different types (suppliers/customers/research institutions) of R&D co-operation is considered, however. This is partly due to data restriction, the database does not offer information on the total number of R&D co-operations.

The explanatory variables:

- *Mandate R&D*: the variable shows the foreign subsidiaries' scope in terms of R&D. It is 1 if R&D related business function(s) were undertaken only or

mainly by the subsidiary and 0 if they were undertaken only or mainly by the foreign investor (HQ).

- *Mandate Management*: the variable shows the foreign subsidiaries' mandate in terms of management. It is 1 if strategic and/or operational management were undertaken only or mainly by the subsidiary and 0 if they were undertaken only or mainly by the foreign investor (HQ).

- *Size*: the variable shows the foreign subsidiaries' size. It is coded 1 if the foreign subsidiary has 1-49 employees, it is coded 2 if the foreign susidiary has 50-249 employees and it is coded 3 if the foreign subsidiary has 250 or more employees.

- *MNEs technology- and knowledge-seeking investment motive*: the variable is 1 if the strategic motive 'Access to location-bound knowledge and technology' was important for foreign investor and it is 0 if this strategic motive was not important for the foreign investor to enter the market.

- *Interaction between importance of the investment motive 'access to location-bound knowledge and technology' and scope in terms of R&D business function*: the interaction term takes 1 if the strategic motive 'access to location-bound knowledge and technology' was important or very important for the foreign investor's decision to enter the market AND R&D related business function(s) were undertaken only or mainly by the subsidiary. It is 0 in all other cases.

- *Regional technological environment* on NUTS 2 level: to measure the subsidiary location's technological environment we included the number of patent application in the regions into the analysis.

- *Regional knowledge stock* on NUTS 2 level: to measure the potential for sourcing regional knowledge we included the regional share of employees with a technical-scientific occupation into the analysis.

In order to control for the foreign subsidiaries' heterogeneity, we included its year and mode of entry, the type of investor, a sectoral dummy and a dummy on the origin of the investor (EU-27 or other) as *control variables*. Also *country dummies* were included in order to account for differences between the countries. East Germany serves as reference country.

A correlation table of the explanatory variables is added in the annex (Table 5).

4.2.1 Firm-level determinants

In the complete sample as well as in all subsamples the level of **R&D mandate** is significantly positive associated with the probability of regional R&D co-operation (H1a), which seems especially the case for linkages to regional customers and research institutions. Results on the effect of **management mandate** in the subsidiary on the likelihood of R&D linkages are significant and positive in the whole sample (H1b), too, albeit this seems to be especially the case for co-operation with regional suppliers and research institutions. Subsidiaries' management mandate seems not to be significantly associated with regional R&D co-operation in the case of customers.

In addition, the estimation results suggest that the foreign subsidiary's **size** has a significantly positive impact on R&D co-operation. This positive effect can be observed throughout all sub samples so that H2 cannot be rejected.

The **investment motive 'access to location bound knowledge and technology'** is significantly positive in the baseline model 4. It turns insignificant, however, when the **interaction term** between R&D scope and knowledge and technology seeking motive is included (H3a). Some of this effect might be explained by the correlation between the interaction term and the variables on the scope in terms of R&D and the investment motive respectively. The interaction term itself is insignificant throughout all samples. A high scope in terms of R&D in the subsidiary and a technology- and knowledge-seeking investment motive of the foreign investor might thus not have additional impact on the likelihood for R&D co-operation with regional actors (H3b).

4.2.2 Regional determinants

Looking at the regional determinants the estimation results show significant outcomes for the whole sample as well as the subsamples - with a negative coefficient, however. These results suggest that the **regional technological environment** measured in number of applied patents per NUTS-2 region is negatively associated with regional R&D linkages (H4a). The estimation results on the **regional knowledge stock** (measured by the share of employees with a technical-scientific occupation) show that it is significantly positive associated with the likelihood of R&D co-operation with

the regional innovation system (H4b). Especially R&D co-operation with regional suppliers is positively associated with the regional knowledge stock.

4.2.3 Control variables and country dummies

Amongst the **control variables** the estimats show that foreign subsidiaries which have entered the market more recently are less likely to have R&D co-operation with the regional innovation system (only in the case of regional suppliers this results is significant, however). Regarding countries of origin it shows that foreign subsidiaries with headquarters within EU-27 are also less likely to cooperate with the regional economy in the area of R&D. This result is even significant for the whole sample and the subsample on research institutions. Mode of entry (greenfield vs. acquisition) and type of investor (financial investor vs. others) as well as the sectoral differences do not seem to play a considerable role for R&D co-operation behaviour between foreign subsidiaries and regional innovation system. The **country dummies** (with East Germany as base category) suggest that the likelihood for technological linkages is less likely in the CEE countries than in East Germany (in some subsamples significanlty so in others not). This might imply that either the willingness to share knowledge between foreign subsidiary and regional innovation system is higher in East Germany or that the regional knowledge base, which makes R&D co-operation worthwhile for the foreign subsidiary, is higher.

5 Discussion and Conclusion

5.1 Summary of results and discussion

Our analysis shows that the generation of new technology does play a role for MNEs to locate in European post-transition economies. The results show furthermore that knowledge exchange is location- as well as firm-specific. There is indeed an interaction in technological activities taking place between the foreign subsidiaries and domestic markets, as 38% of the foreign subsidiaries in East Germany and 20% of the foreign subsidiaries in the selected CEE countries did source and transfer knowledge and technology by R&D co-operation from and to the regional innovation system.

5.1.1 Foreign subsidiary's mandate and size

Supporting our first argument, we find that the foreign subsidiary's mandate in terms of R&D and mandate in terms of management is positively associated with technological linkages to the regional innovation system. The split of the sample into technological linkages with different partners in the region - suppliers, customers, and reserach institutions - shows no differences with regard to the influence of the foreign subsidiary's mandate in terms of R&D. In view of the impact of the susbidary's managerial mandate we find mixed results in the sub samples, however. It seems that R&D linkages to customers are less influenced by the level of management reponsibility than those to suppliers and research institutions. This result might imply that knowledge exchange with customers is not so much depending on management mandate, maybe because knowledge is rather passed on from the MNEs subsidiary to the regional customer (and in most cases not from the customer to the foreign subsidiary) which might be the other way around with suppliers and research institutions. Our results with regard to scope are in line with recent research on less developed economies which emphazise the importance of the foreign subsidiary's mandate or autonomy for the creation of linkages or knowledge and technology exchange with the domestic economy (see f.e. Günther, Stephan, and Jindra 2008). Focusing on foreign subsidiaries' linkages to suppliers in the CEE region, Giroud, Jindra, and Marek (2012) for example find an positive influence of the subsidiary's mandate on technological business functions while the level of autonomy over production and operational management has no significant influence. In addition, Jindra, Giroud, and Scott-Kennel (2009) show that the subsidiary's mandate influences both extent and intensity of backward and forward linkages with the domestic environment - with a positive sign regarding autonomy over supply and logistics and product development on the extent of backward linkages and regarding autonomy over distribution and sales on the extant and intesity of forward linkages. Results on the impact of the foreign subsidiary's mandate are rather mixed in sum, depending on the kind of linkages and the type of co-operation partners. As we focus on R&D linkages and therefore vaule-adding FDI only, it seems that the foreign subsidiary's scope is especially important due to the knowledge and technology intense type of co-operation. From an empirical view, results on the impact if the foreign subsidiary's size are mixed. Giroud, Jindra, and Marek (2012) and Jindra, Giroud, and Scott-Kennel (2009) find in their paper a significant but negative impact

of size on backward and forward linkages respectively. On the other hand, results in Berlderbos, Carree, and Lokshin (2006) as well as in Fritsch and Lukas (2001) suggest positive effects on R&D co-operation for large firms - so do Kudic, Pyka, and Guenther (2012) for co-operation in general. Confirming our argument, we find a positive impact of the foreign subsidiary's size regarding technological linkages, which implies that larger foreign subsidiaries are more likely to co-operate in the area of R&D with the regional innovation sytem.

5.1.2 MNE's investment motive 'access to location-bound knowledge and technology'

Regarding the market entry motivation the empirical evidence supports our argument only partly: we find a significantly positive relation between the importance of the investment motive 'access to location bound knowledge and technology' and the probability of technological linkages with the regional innovation system - at least in the model specification without interaction term. These results are in-line with Santangelo (2012) who find that competence-seeking subsidiaries are better embedded with domestic actors. Günther, Stephan, and Jindra (2008) tested for a home-base-augmenting strategy of the foreign subsidiary and find that foreign subsidiaries following this strategy are more likely to source technological knowledge from the East German innovation system. Hence, it seems, that the MNE's market entrance motivation does play some role when explaining technological interaction between the foreign subsidiary and the regional innovation system. In our case, however, the MNE's investment motive is not as strongly related to the foreign subsidiary's technological co-operation behaviour as we assumed. This might be explained by a change in the foreign subsidiary's orientation over the time of its existance: it is possible that the MNE entered the market without an technology-seeking investment motive years ago, it might nonetheless tap into knowledge at present or the other way around. Furthermore, the foreign subsidiary can follow more than one investment strategies at the same time depending on the technological field of investment (Criscuolo, Narula, and Verspagen 2002; Günther, Stephan, and Jindra 2008). If we interact the subsidiary's high responsibility in terms of R&D and the importance of the market entry motive 'acces to location bound knowledge and technology', we find no additional significant evidence for technological linkages, neither for the importance of the technology-seeking investment motive nor for the interaction term

itself. The argument on the interaction between scope and investment motive can therefor be rejected.

5.1.3 Regional technolgical endowment and knowledge stock

We argued that the higher the regional technological endowment, the more inclined are foreign subsidiaries to realize technological linkages with the regional innovation system. Throughout all samples we find negative but significant results, which seems rather surprising on first sight, but is in-line with outcomes on technology sourcing from Günther et al. (2008) for East Germany. They explain these negative effects with the foreign subsidiaries' reluctance to share knowledge about technological development with domestic partners. The results of our other regional determinant seems to weaken this interpretation, however. According to our hypothesis we expected that the endowment with high skilled human capital is positively associated with technological linkages of foreign subsidiaries. For the whole sample and all subsamples we find significantly positive influence on the likelihood of regional technological co-operations. Empirical studies confirm that knowledge sourcing is influenced by the quality of knowledge sources. Filippov and Duysters (2011) find that subsidiaries accumulate knowledge and competences from interaction with their environment whereas universities and research centers serve as sources of knowledge especially for R&D. Günther, Jindra, and Stephan (2009) find empirical evidence that knowledge skills and technology are relevant for foreign subsidiaries located in CEE and East Germany. The oppositional outcomes on the regional determinants in our empirical analysis seem to suggest that the foreign subsidiary's technological activities are still mainly directed at benefitting from the firm's existing knowledge base, as regional inventions are not positively associated with regional R&D co-operation. The transfer of knowledge and technology seems yet to be influenced by the host country's regional technological capabilities, as the regional knowledge stock is positively associated with regional R&D co-operation. These results support for example Frost (2001) and March (1991) in the suggestion that the source of the foreign subsidiary's innovative activities can mainly be found elsewhere, most likely in the firm's headquarter while the adaption and advancement of this existing knowledge and technology might indeed be motivated by the host country's regional capabilities, as suggest the positive influence of the region's knowledge stock in terms of human capital in our analysis. In short, these results might indicate that long-term learning processes between foreign

subsidiary and regional innovation system are less likely than the benefit of rather short-term access to well-educated human capital.

5.2 Conclusion

A country's position in the catching-up process to industrialization does not only depend on the quantitiy but also on the character of incoming FDI (Gauselmann and Marek 2012). The ability of the European post-transition countries to link with value-adding FDI and raise their technological capabilities are the essential issues to guarantee increasing productivity and industrial upgrading in the long term (Narula and Guimón 2010). MNEs have located their general economic activities across regions and countries, especially manufacturing and sales in the European regions. In recent years this internationalisation has more and more included R&D activities. R&D units which have mainly been centrally organized at the headquarter in the past become now further geographically dispered on the subsidiary level (Narula and Guimón 2010). Thus, increased competition and technological complexity encourages MNEs to relocate R&D investments and co-operate with firms and institutions in the target location.

In sum, the regression results based on 2009 survey evidence show that firm- as well as region-specific determinants influence the heterogeneity of foreign subsidiaries' technological linkages with the regional innovation system. Results suggest that especially the foreign subsidiary's scope in terms of R&D and management, its size and the regional knowledge stock are positively associated with these linkages.

The European post-transition regions seem to catch up as target locations for knowledge and technology sourcing of MNEs. The regression results in the selected post-transition regions show little difference to the explanatory determinants of studies on developed countries. This suggests that the European post-transition countries are increasingly developing towards knowledge-based economies.

Further research on regional determinants seems reasonable. It might also be worthwhile to investigate the relation bewteween technological linkages and foreign subsidiary' innovative activities or the impact of technological intra-firm relationships between foreign susbidiary and MNE to find out more about its linkage creation.

6 Annex

Table 2: Summary of variables, their sources, and expected impact on dependent variable

Variable Name	Description	Data source	Expected impact
Scope R&D	foreign subsidiary's scope in terms of R&D	IWH	+
Scope management	foreign subsidiary's scope in terms of management	IWH	+
Knowledge and technology seeking investment motive	MNE's strategic motive 'Access to location-bound knowledge and technology'	IWH	+
Interaction term	interaction between R&D scope and knowledge and technology seeking motive	IWH	+
Regional technological endowment	number of patent applications in the region	European Patent Office	+
Regional knowledge stock	regional share of employees with a technical-scientific occupation	Eurostat	+
Subsidiary size	foreign subsidiary's number of employees (0-49, 50-249, 250 and more)	IWH	+
Year of entry	MNE's year of entry: before 1990, 1990-2000, 2001-2009	IWH	-
Mode of entry	MNE's mode of entry: greenfield vs acquisition	IWH	-
Origin of investor	MNE's home country: EU-27 country vs other	IWH	-
Type of investor	foreign subsidiary's type of investor: financial investor vs other	IWH	+
Branch	foreign subsidiary's branch: industry vs selected services according to NACE	IWH	+/-
Country dummies	CZ, HU, PL, RO, SLO; reference country: East Germany	IWH	-

Table 3: The 52 NUTS-2 regions included in the dataset

East Germany
1 Berlin
2 Brandenburg-Nordost
3 Brandenburg-Südwest
4 Mecklenburg-Vorpommern
5 Chemnitz
6 Dresden
7 Leipzig
8 Sachsen-Anhalt
9 Thüringen

Hungary
10 Dél-Alföld
11 Dél-Dunántúl
12 Közép-Dunántúl
13 Közép-Magyarország
14 Nyugat-Dunántúl
15 Észak-Alföld

Slovakia
16 Bratislavský kraj
17 Stredné Slovensko
18 Východné Slovensko
19 Západné Slovensko

Czech Republic
20 Jihovýchod
21 Jihozápad
22 Moravskoslezsko
23 Praha
24 Severovýchod
25 Severozápad
26 Strední Cechy
27 Strední Morava

Romania
28 Bucuresti - Ilfov
29 Centru
30 Nord-Est
31 Nord-Vest
32 Sud - Muntenia
33 Sud-Est
34 Sud-Vest Oltenia
35 Vest

Poland
36 Dolnoslaskie
37 Kujawsko-Pomorskie
38 Lubelskie
39 Lubuskie
40 Lódzkie
41 Malopolskie
42 Mazowieckie
43 Opolskie
45 Podkarpackie
46 Podlaskie
47 Pomorskie
48 Slaskie
49 Swietokrzyskie
50 Warminsko-Mazurskie
51 Wielkopolskie
52 Zachodniopomorskie

Table 4: Results of the logit estimation on technological linkages for the whole sample and sub-samples regarding suppliers, customers, and research institutions

	(1) baseline 1	(2) baseline 2	(3) baseline 3	(4) baseline 4	(5) whole sample	(6) suppliers	(7) customers	(8) research institutions
Firm-specific determinants								
Scope R&D	1.349***			1.174***	1.321***	1.031**	1.652***	0.965***
	(0.308)			(0.207)	(0.322)	(0.449)	(0.532)	(0.335)
Scope management	0.479*			0.523*	0.523*	1.004**	0.271	0.528*
	(0.280)			(0.295)	(0.296)	(0.458)	(0.409)	(0.316)
Subsidiary size	0.436***			0.639***	0.643***	0.357**	0.674***	0.648***
	(0.436			(0.138)	(0.139)	(0.172)	(0.188)	(0.146)
Knowledge and technology seeking investment motive	0.375			0.374*	0.531	0.512	0.908	0.244
	(0.309)			(0.191)	(0.325)	(0.470)	(0.556)	(0.341)
Interaction between R&D scope and knowledge and technology seeking motive	-0.149				-0.242	0.00727	-0.659	-0.0264
	(0.377)				(0.401)	(0.551)	(0.633)	(0.421)
Regional determinants								
Regional technological endowment		0.000588*		-0.00110**	-0.00112**	-0.00104*	-0.00132**	-0.000875*
		(0.000321)		(0.000486)	(0.000486)	(0.000600)	(0.000659)	(0.000506)
Regional knowledge stock		0.0146		0.0473**	0.0483**	0.0616***	0.0697**	0.0427**
		(0.0119)		(0.0188)	(0.0189)	(0.0233)	(0.0284)	(0.0200)
Control variables								
Year of entry			-0.327**	-0.266	-0.271	-0.487**	-0.257	-0.131
			(0.161)	(0.174)	(0.174)	(0.216)	(0.233)	(0.182)
Mode of entry			-0.488***	-0.267	-0.269	-0.273	-0.158	-0.271
			(0.183)	(0.197)	(0.197)	(0.251)	(0.274)	(0.209)
Origin of investor (EU-27 dummy)			-0.401*	-0.400*	-0.397*	0.198	-0.126	-0.540**
			(0.212)	(0.229)	(0.229)	(0.304)	(0.310)	(0.233)
Type of investor			0.728*	0.636	0.622	0.540	0.608	0.435
			(0.387)	(0.413)	(0.414)	(0.507)	(0.514)	(0.423)
Branch			-0.061	0.0387	0.0407	0.0571	0.0855	0.00578
			(0.178)	(0.198)	(0.198)	(0.252)	(0.270)	(0.209)
Country dummies								
Czech Republic			-1.052***	-1.699***	-1.708***	-1.405***	-2.124***	-1.439***
			(0.275)	(0.389)	(0.389)	(0.506)	(0.628)	(0.408)
Hungary			-0.087	-0.326	-0.349	-1.376**	-1.852**	-0.175
			(0.342)	(0.403)	(0.405)	(0.666)	(0.792)	(0.414)
Poland			-0.477**	-0.729**	-0.727**	-0.437	-0.432	-0.803**
			(0.240)	(0.300)	(0.300)	(0.374)	(0.384)	(0.323)
Romania			-1.489***	-1.712***	-1.702***	-0.646	-1.569**	-1.742***
			(0.379)	(0.444)	(0.444)	(0.507)	(0.678)	(0.505)
Slovakia			-0.691**	-1.515**	-1.530**	-0.965	-1.564*	-1.053*
			(0.529)	(0.595)	(0.596)	(0.728)	(0.853)	(0.598)
Constant	-3.119***	-1.527***	0.820	-3.071***	-3.195***	-4.564***	-5.526***	-3.337***
	(0.403)	(0.340)	(0.524)	(0.900)	(0.925)	(1.185)	(1.341)	(0.973)
Observations	727	727	727	727	727	727	727	727
Pseudo R2	0.083	0.010	0.063	0.152	0.155	0.108	0.131	0.127

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5: Correlation table of explanatory variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	CZ	HU	PL	RO	SK
(1) Scope R&D	1																
(2) Scope management	0,360	1															
(3) Size	-0,074	0,000	1														
(4) Investment motive	0,011	0,006	0,051	1													
(5) Interaction	0,636	0,215	0,004	0,559	1												
(6) Regional tech. endowment	0,131	0,049	-0,194	-0,036	0,063	1											
(7) Regional knowl. stock	0,004	0,015	-0,182	0,005	0,034	0,452	1										
(8) Year	0,086	-0,030	-0,111	-0,027	-0,002	0,079	0,033	1									
(9) Mode	-0,139	-0,077	-0,114	-0,012	-0,086	-0,089	-0,003	-0,281	1								
(10) Origin	-0,037	-0,011	0,031	-0,063	-0,047	-0,186	-0,149	-0,059	0,099	1							
(11) Tyoe	0,075	0,021	-0,038	-0,060	-0,023	0,017	0,065	0,170	-0,080	-0,088	1						
(12) Branch	0,038	-0,056	-0,269	-0,008	0,034	0,144	0,258	0,079	0,070	-0,021	0,060	1					
(13) CZ	-0,121	-0,040	0,018	0,076	-0,037	-0,248	0,359	0,005	0,059	0,049	0,008	-0,009	1				
(14) HU	-0,099	0,096	0,095	0,066	-0,065	-0,091	-0,038	-0,061	-0,046	-0,013	0,030	-0,039	-0,116	1			
(15) PL	-0,069	-0,027	0,100	-0,046	-0,048	-0,285	-0,245	-0,115	0,113	0,113	-0,053	-0,091	-0,222	-0,123	1		
(16) RO	0,013	-0,046	0,129	0,056	0,046	-0,241	-0,496	-0,030	-0,004	0,078	-0,033	-0,125	-0,162	-0,090	-0,171	1	
(17) SK	-0,021	0,006	0,114	0,070	0,025	-0,112	0,050	-0,021	0,000	-0,020	0,001	-0,011	-0,081	-0,045	-0,086	-0,063	1

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