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The Impact of FDI on Innovation in Target Firms

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Joel Stiebale and Frank Reize*

The Impact of FDI on Innovation in Target Firms

Abstract
This paper contributes to the ongoing debate on the welfare effects of foreign direct investment by investigating the effects of cross-border mergers and acquisitions on innovation activities in target firms. The empirical analysis is based on survey and ownership data for a large sample of small- and medium-sized German firms. After controlling for endogeneity and selection bias, it is found that foreign takeovers have a large negative impact on the propensity to perform innovation activities and a negative impact on average R&D expenditures in innovative firms. Furthermore, innovation output, measured as the share of sales from product innovations is not significantly affected by a foreign takeover for a given amount of innovation efforts. Hence, the estimation results do not show any evidence of significant technology spillovers through foreign direct investment in form of a higher innovation success.

JEL Classification: D21, F23, G34, C31, O31, O33

Keywords: Multinational enterprises, mergers and acquisitions, innovation

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1. Introduction

Foreign direct investment (FDI) inflows, most of which are mergers and acquisitions have increased all over the world and inflows to Germany have more than tripled within ten years to reach a volume of 334 billion € in 2004 (Deutsche Bundesbank 2006). Governments all over the world spend a lot of effort on attracting inward FDI, although empirical results regarding the host country welfare effects are mixed (see Lipsey and Sjöholm 2005 for an overview). These empirical approaches usually relate labor or total factor productivity of local firms to foreign ownership or to the presence of foreign investors in the same sector or region. Positive coefficients for the FDI measure are then interpreted as evidence for technology spillovers. Many studies comparing productivity of domestic and foreign-owned firms indeed find that firms with foreign ownership outperform domestic firms (e.g. Arnold and Javorcik 2005, Harris and Robinson 2003, to mention a few).

However, recent work has cast doubt on the direction of causality - because of simultaneity and correlation of foreign ownership with characteristics that are unobserved by the researcher - and argues that the effects of previous studies are at best overestimated (Benfratello and Sembenelli 2006). In addition, differences in productivity are only a very rough measure of technological performance. As the main result of technological progress and innovation are new and improved products not all relevant advances might show up in an equation that relates value added to input factors. Hence, a more adequate way is to look at innovation indicators and to evaluate the impact of foreign takeovers on innovation input, i.e. expenditures for research and development (R&D) or innovation activities, and innovation output, i.e. product and process innovations, in target firms.

There are reasons to predict that firms might benefit from the participation of foreign firms. First, economic theory explains the existence of multinational enterprises by ownership of firm specific assets which are necessary to overcome the large sunk costs that arise when a foreign market is entered. Theoretical models predict and empirical studies confirm that firms that engage in international activities hold a productivity advantage compared to their local competitors and their competitors in the host country. Specifically, Helpman et al. (2004) show in a theoretical model, that firms conducting FDI are more productive than firms that just conduct exports or operate solely on the domestic market. These findings are also confirmed by some empirical studies. Analyzing German firm level data, Arnold and Hussinger (2006) and

Wagner (2006a) find that the productivity distribution of multinational enterprises is superior to that of domestic firms.

Second, FDI has been identified as a potential channel for international technology diffusion (Veugelers and Cassiman 2003). A theoretical approach of Markusen (1995) argues that firm-specific assets in multinational enterprises (MNEs) have a public good character within firms and that technology is transferred across countries from MNEs´ headquarters to their affiliates. Empirical studies, such as Le Bas and Sierra (2001) and Pantel and Vega (1999) find that multinational enterprises often invest abroad in technological areas in which they are strong in their home country, which suggests that firms might benefit from being acquired by a multinational enterprise.

From a theoretical point of view, the relationship between research and development and foreign direct investment is unclear. MNEs' affiliates might benefit from technology transfer from their parents, which reduces the incentives to perform R&D activities (Hughes 1986, Kumar 1987). Further, there is evidence that most firms tend to locate their R&D activities close to their headquarters and their main corporate production unit (Howell 1984). It is usually argued that this is due to the long term strategic importance of R&D and the aim of managers to track these activities. In addition, mergers and acquisitions are likely to result in cost saving activities (Jensen 1986). They may also lead to organizational complexity and favor organizational structures with higher financial controls which imply a lower R&D intensity (Hitt et al. 1996). This argument might especially matter for cross-border deals because of differences in corporate culture. However, Lall (1983) points out that the transfer of new technologies that is often associated with FDI might stimulate R&D activities, because knowledge is necessary to implement a new technology and to adapt it to the local production process.

Foreign ownership might also affect a firm's innovation output. From a theoretical point of view the effect of foreign ownership on a firm's innovation output is ambiguous. On the one hand there might be a technology transfer from foreign parents to their affiliates (Markusen 1995), if foreign parents want to exploit their firm-specific assets in the host country. On the other hand, Dunning and Narula (1995) find that technology seeking can also be a motive for FDI and Watts (1981) argues that innovations might be exploited mainly in the region where ownership is located rather than in the region where the innovation took place.

The purpose of this paper is twofold. First, it analyzes in which direction foreign takeovers affect R&D activity. Second, it evaluates whether there is an effect on innovation output in target firms. The paper is organized as follows. In section 2, previous research on foreign ownership and innovation is discussed. Section 3 provides a description of the data, section 4 describes the empirical model. Results of the empirical analysis are presented in section 5, section 6 concludes.

2. Previous Research

Several attempts have been made to analyze differences in innovation activities between national and foreign-owned firms empirically. Lofts and Loundes (2000) find that there is a weakly positive relationship between innovation intensity and foreign ownership in Australian companies. Bishop and Wiseman (1999) analyze a sample of British producers of military goods and find that there is no direct relation between foreign ownership and the propensity to innovate, but an indirect negative effect, because it reduces the probability that a firm performs R&D activities. In contrast, Love et al. (1996) provide evidence that foreign-owned firms in Scotland are more innovative.

Lööf et al. (2006) analyze the effect of foreign ownership on innovative activity using CIS data for northern European countries. Their results indicate that domestic firms do hardly differ from foreign-owned firms with respect to innovation input, innovation output and productivity. Balcet and Evangelista (2005) compare multinational and national firms in Italy. Once they control for firm and sector characteristics, multinational and domestic firms differ only in their innovation strategy but not in their innovation intensity. Sadowski and van Beers (2003) find that multinational affiliates in the Netherlands are more likely to introduce new products than domestic firms, but that there is no difference in the propensity to introduce drastic innovations. Griffith et al. (2004) compare the R&D intensities of foreign-owned firms, multinationals with domestic headquarters and purely domestic firms across sectors. The results show that foreign-owned firms are less R&D intensive than domestic firms, but are across all sectors equally or more R&D intensive than firms that operate solely on the domestic market.

Erdilek (2005) shows that foreign-owned firms in Turkey have a higher propensity to perform innovation activities as well as a higher R&D intensity. Castellani and Zanfei (2004) compare innovation activities of national, multinational and foreign-owned firms for a sample of mostly large Italian firms and report a positive correlation between foreign ownership and R&D. None of these studies distinguishes between Greenfield investments (newly founded firms or production units) and foreign takeovers. Further, they treat foreign ownership as exogenous. Thus, they only measure a correlation between foreign takeovers and innovation in the presence of unobserved factors that influence foreign takeovers and innovation efforts.

Bertschek (1995) estimates a positive relationship between a firm's propensity to introduce new products and processes and the market share of foreign-owned firms in the same industry for a sample of German manufacturing firms. The data set used in this study does not allow for a distinction between Greenfield investments and foreign takeovers. Blind and Jungmittag (2004) confirm the result for industry-level FDI, but estimate a negative correlation between foreign ownership and the propensity to innovate for German service firms. As they do not control for innovation input, it is not clear whether this result is due to lower R&D efforts or a lower innovation success. Bertrand and Zuninga (2006) find that cross-border mergers and acquisitions had no impact on an industry's R&D intensity in the host country on average, but a positive impact on R&D intensity in medium tech industries. Since their empirical model is estimated at the industry level, the researchers cannot distinguish between the impacts on target firms and the impacts on non-merging competitors. Hence, it is not clear whether the results are driven by the aggregation of firms within industries.

Criscuolo et al. (2005) estimate "knowledge-production functions" controlling for firms´ international activities. Dependent variables are the introduction of new products and processes and the share of sales that is generated with product innovations. They find that exporters, as well as multinational enterprises and firms with foreign ownership generate more knowledge conditional on R&D intensity and some other control variables, but this effect disappears when they estimate fixed effects for two cross-sections. Wagner (2006b) confirms the positive correlation between innovation output and international activities using survey data for German firms. Almeida and Fernandez (2006) find that majority foreign-owned firms have a lower probability to introduce new technologies in developing countries, but minority foreign-owned firms display a higher probability than domestic firms, after controlling for several additional characteristics such as industry, firm size and engagement in international markets. They do neither control for innovation input nor for endogeneity of foreign takeovers.

Johansson and Lööf (2005) compare the innovation intensity between domestic multinationals, foreign-owned firms and domestic firms using a cross section of Swedish firms, using regression models and nearest neighbour matching. Their regression analysis uses a foreign ownership dummy that is treated as exogenous. Furthermore, they use a matching technique to identify differences in the mean values of various innovation activities, where the control group consists of firms that belong to a national group. In a methodological similar paper, Falk and Falk (2006) find that foreign-owned firms in Austria have an innovation intensity that is about 30 to 40 per cent lower than the innovation intensity of national firms. Yet, this approach only measures a causal effect if selection into multinational enterprises happens solely on the basis of observable characteristics or if differences in unobservable characteristics of the treatment and the control group do not affect the outcome measure (Heckman et al. 1993).

This assumption of conditional independence is very restrictive, though. It is difficult to support this assumption, since the cross-sectional nature of the data does not even allow the researchers to control for time-invariant unobserved heterogeneity. Consequently, both studies compare foreign-owned firms to national firms and do not directly asses the impact of foreign takeovers. All in all, the results regarding the relationship between foreign investors and innovation are very mixed and usually there is no adequate assessment of the counterfactual situation, i.e. the question how innovative a domestic firm would be, if it was foreign-owned, and vice versa. This deficiency will be addressed in our own contribution by using an empirical approach that explicitly controls for the endogeneity of foreign takeovers.

3. Data and descriptive statistics

The data used in this paper come from two different sources. The first data set is an annually repeated survey, the "KfW-Mittelstandspanel", which is representative for German firms with up to 500 million € annual sales. This survey is conducted by "KfW Bankengruppe" in Germany. For a detailed description see Reize (2004a). The different waves contain 10,000-15,000 observations respectively, corresponding to a response quote between 15 and 21%. The "KfW-Mittelstandspanel" includes information on firms´ investment and innovation activities as well as firm characteristics, such as the number of employees and sales for the current and the previous year, share of skilled employees, industry, finance etc. Regarding qualitative innovation indicators, firms are asked whether they performed innovation activities and whether they perform own R&D activities. More specifically, they are asked whether they were engaged in continuous or occasional R&D activities in the last 3 years. Further innovation indicators are successful product and process innovations and whether these innovations were new to the market. Quantitative innovation indicators are two measures of R&D intensity - the share of R&D in total sales and the percentage of work time spent with R&D - and the share of sales from product innovations in total sales. Only the waves including information for the years 2002 and 2004 are used, since innovation indicators were not surveyed for the year 2003.

The second data set used is the AMADEUS database, a database that provides information on financial data as well as ownership and subsidiary information for European firms, including more than 812.000 German firms.[2] Ownership information includes the country of origin, the type of shareholder (private investor, bank, industrial company etc.) and the percentage of equity held by each shareholder. There is a specific shortcoming of this database which affects most empirical studies using it: While balance sheet data is available for up to ten years, ownership information is only available at one point in time. Hence, most empirical studies using the AMADEUS database treat ownership as constant over time. This paper addresses this problem by merging different updates of the database to track changes in ownership. The available updates refer to the years 2004, 2002 and 2000. Each of the three updates provides information on ownership structure and financial data items for the corresponding year. Thus, changes in the ownership structure can be tracked over time. AMADEUS firms are merged with the observations from the "KfW-Mittelstandspanel" by a common firm identifier resulting in 11,085 observations.

Foreign ownership is defined as follows. At least one foreign investor holds ten or more percent of equity via direct or indirect participation, e.g. through a holding company. The 10% threshold is in line with the OECD benchmark definition of FDI (OECD 1996) and is standard in the economic literature for analysing FDI spillovers. However, there are only few firms with foreign ownership in the sample that are not majority owned. In 92% of all firms with foreign ownership in the sample one foreign investor holds at least 50%, while in 98% of these firms one foreign investor holds 25% or more. 57% of these firms are wholly owned foreign subsidiaries. Hence, the impact of minority foreign ownership as well as the acquisition of minority shares is not analyzed further.

[2] AMADEUS is provided by Bureau van Dijk and Creditreform in Germany. AMADEUS updates 136, 113 and 88 are used. The AMADEUS database has been used in numerous empirical studies on FDI, most of them measuring productivity and employment effects (see e.g. Bud et al. 2005, Konings and Murphy 2006, Helpman et al. 2004).

A firm that was subject to a foreign takeover is defined as one with foreign ownership in the current year but not in the initial year. Thus, it is possible to estimate the impact of foreign takeovers and not the effect of foreign ownership *per se*, since Greenfield investments are excluded by this procedure. The reason to exclude Greenfield investments is that there is no reasonable definition of a counterfactual situation. These firms would not exist, if they were not founded by a foreign investor, hence it does not make sense to predict innovation activity or any other outcome measure for the case they were not foreign-owned. After deleting observations with missing values in the variables of interest as well as firms that had foreign ownership constantly, some 7,000 observations are left for the analysis. The overall number of firms that were acquired by a foreign investor is 210 in the combined data set, but is reduced to 185 in the final sample used for estimation.

Table 1 shows some summary statistics for national and foreign-owned firms including all variables that are used in this paper. Foreign-owned firms are engaged in R&D activities considerably more often than national firms. Some 49% of all foreign-owned firms have spent a positive amount on R&D activities, which is almost twice the share of national firms. The same is true of the share of firms that engage in R&D continuously, as well as of the average share of R&D in total sales. Regarding innovation output we see that a higher percentage of foreign-owned firms have introduced new products and processes and have a higher share of sales from product innovations. But also other characteristics which are probably positively correlated with innovation, like average human capital, capital intensity and firm size, are on average higher in these firms. To provide a comprehensive portrait of market structure tables 2 and 3 show the share of FDI firms across sectors and size classes, respectively. The share of foreign takeovers is considerably above average in R&D intensive manufacturing industries like vehicle construction and precision instruments as well as in bigger firms. To analyze the impact of a foreign takeover conditional on observable as well as on unobservable characteristics, a multivariate analysis is performed in the next section.

4. Empirical strategy

4.1 Empirical model

A model that accounts for both structural zeros and endogeneity is specified to evaluate the impact of foreign takeovers on innovation. Structural zeros arise because a lot of firms report zero R&D expenditures and endogeneity arises from the fact that unobserved factors that influence R&D activities might also affect the propensity of a foreign takeover. The approach accounts for the fact that the determinants to perform R&D or innovation activities might be different from the determinants of the actual R&D expenditures. As an example, it is a stylized fact, that the probability of doing R&D rises significantly with firm size, but R&D intensity is usually not affected by firm size (Cohen and Levine 1989). Also, the impact of foreign investors on R&D expenditures might be different from the impact on the decision to engage in R&D.

The empirical method builds on a framework for analyzing the determinants of innovation input and output that was originally proposed by Pakes and Griliches (1984) and further developed in Crépon et al. (1998). The so called "CDM"-model was applied and partly modified in further studies (e.g. Janz et al. 2004, Lööf and Heshmati 2006 to mention a few).[3] The original model consists of four equations that relate productivity to innovation output, innovation output to a firm's R&D expenditures and R&D expenditures as well as the propensity to engage in R&D to various firm and market characteristics. In the first step we focus on R&D expenditures. The determinants of R&D expenditures are usually estimated as a generalized tobit model. To evaluate the effect of foreign takeovers on innovation effort, in our approach the generalized tobit model is augmented with an FDI equation:

$$(1)\ FDI_i = \begin{cases} 1, \text{ if } FDI_i^* = w_i'\gamma + u_i > 0 \\ 0, \text{ else} \end{cases}$$

$$(2)\ I_i = \begin{cases} 1, \text{ if } I_i^* = x_{1i}'\beta_1 + \delta_1 FDI_i + \varepsilon_{1i} > 0 \\ 0, \text{ else} \end{cases}$$

$$(3)\ RD_i = \begin{cases} RD_i^* = x_{2i}'\beta_2 + \delta_2 FDI_i + \varepsilon_{2i} \text{ if } I_i^* > 0 \\ 0, \text{ else} \end{cases}$$

Equations (1) and (2) specify two latent variables that determine the propensity of a foreign takeover and the probability to engage in R&D. *FDI* takes the value of 1 if firm *i* was acquired by a foreign investor, while equation (2) models the propensity to engage in R&D: *I* equals one for firms that engage in R&D. In addition, alternative specifications are employed, e.g. the propensity to be engaged in *continuous* R&D. Equation (3) determines the height of innovation input, which is defined as the logarithm of R&D expenditures per employee.

[3] Some of these studies are surveyed in Hall and Mairesse (2006). Lööf et al. (2006) compare foreign and domestically owned firms within the CDM framework. In their study there is no equation determining FDI, hence the regressor is treated as exogenous.

The error terms of the three equations are assumed to be jointly normally distributed with zero means and are allowed to be freely correlated, which yields the following variance-covariance matrix:

$$\Sigma = \begin{pmatrix} 1 & \sigma_{u1} & \sigma_{u2} \\ \sigma_{u1} & 1 & \sigma_{12} \\ \sigma_{u2} & \sigma_{12} & \sigma_{\varepsilon_2}^2 \end{pmatrix}$$

The variances of u_i and ε_{1i} are normalized to one for identification.

A problem that is addressed by this specification is that FDI is potentially endogenous in both equations where it appears as a regressor. Unobserved shocks that affect future profitability and the returns to innovation will also affect the profitability of a foreign takeover. Further there is evidence that acquisition of innovative assets can be a motive for cross-border mergers and acquisitions (Frey and Hussinger 2006). Thus, some kind of simultaneous or two-step estimation of the equation system is necessary. Since two-step estimators are generally less efficient and adjusting standard errors in two-step estimation with a bivariate selection rule is very cumbersome, the model is estimated by full maximum likelihood.[4] Identification requires at least one variable that appears in w_i but not in x_{1i} or x_{2i}. Further, the model is only poorly identified if there are no variables that appear in equation (2) but not in (3), since in that case identification critically hinges on the functional form.

In addition, the model is only consistent if a recursive structure is imposed (Maddala 1983, Lewbell 2005), i.e. if none of the endogenous variables appears in the equation determining a foreign takeover and *FDI* is the only endogenous variable that appears in the equations determining the propensity to engage in R&D and R&D expenditures. This requirement is met since the impact of a takeover in the past on R&D engagement today is evaluated. The estimation is run for a pooled cross section, since estimating a model with fixed effects would reduce the number of foreign takeovers in the sample substantially as only takeovers between 2002 and 2004 could have been taken into account. Standard errors are clustered to allow for interdependence between repeated observations, as some firms appear twice in the sample, i.e. error terms are assumed to be independent across, but not necessarily within clusters.

[4] See the Appendix for the likelihood function of this model and Reize (2001) or Reize (2004b) for a derivation of the log likelihood function and another application of this model.

In line with the CDM model, our specification comprises a further equation that relates innovation output to R&D expenditures. To evaluate the effect of foreign takeovers on innovation output, the FDI variable is included as a regressor.

$$(4)\ P_i^* = \alpha RD_i + x_{3i}^{'}\beta_3 + \delta_3 FDI_i + \varepsilon_{3i}$$

A positive value of δ_3 would indicate a technology spillover or a knowledge transfer from the foreign parent company to the target firm. Three different measures for innovation output, P_i, are used. One is the share of innovation sales in total sales. Unfortunately, this variable is only available in categories 0%-10%, 11%-25%, 26%-50%, 51%-100%. The other two measures are binary indicators that take the value of one if the firm has introduced at least one new product or process respectively. Determinants of innovation output are R&D intensity, human capital, physical investment and external knowledge sources, i.e. the same factors that also influence the innovation input.

Since R&D is potentially endogenous in the innovation output equation the predicted values for R&D intensity, calculated from equations (1)-(3) are used instead of the actual values. As suggested by Griffith et al. (2006) it might be more appropriate to use the expected latent R&D intensity as regressor in the innovation output equation, since not all firms report R&D activities, but almost all firms spent some time on innovation efforts. Therefore, equation (4) is estimated with the expected latent R&D intensity ($E[RD_i^* \mid x_{2i}, FDI_i, I_i = 1]$) for all firms.[5] Further, the generalized residuals from equations (1) and (2) – the inverses of Mill's ratios- λ_{FDI} and λ_{RD} - are included to take into account the selectivity of innovative firms and the possible endogeneity of FDI.[6] Hence, the equation for innovation output becomes:

$$(5)\ P_i^* = \alpha R\hat{D}_i^* + x_{3i}^{'}\beta_3 + \delta_3 FDI_i + \sigma_{3u}\hat{\lambda}_{FDI} + \sigma_{31}\hat{\lambda}_{RD} + \tilde{\varepsilon}_{3i}$$

The most efficient estimation procedure for the innovation sales equation would be an ordered probit with known thresholds. But the inclusion of the inverses of Mill's ratios on the right hand side would cause further complications such as a non-normal distribution and heteroscedasticity of the error term, which would lead to inconsistent estimates if not explicitly modelled in the likelihood function. Therefore the model is estimated as a linear regression and the values for innovation sales are set to the logarithm of the interval mean. This procedure is usually seen as a

[5] See Vella (1993) for the calculation of the expected value of latent variables.
[6] See the Appendix for the definition of the inverses of Mill's ratios for the bivariate case.

good approximation for models with interval-coded data (Wooldridge 2002, p.509) and was also used in the context of R&D and innovation output by CDM. For the same reasons the equations for the binary indicators for product and process innovations are estimated as a linear regression, i.e. a linear probability model.

Although this estimation procedure yields consistent parameter estimates, standard errors have to be corrected. Besides the bias resulting from heteroscedasticity, this is because predicted R&D intensity and the two inverses of Mill's ratios are estimated regressors and hence are measured with sampling error. To adjust standard errors for the use of estimated regressors, bootstrapping with 200 replications is performed. The resampling method is adjusted for the fact that two different cross-sections with partly repeated observations are used.

4.2 The model specification

The innovation input equations (equations 2 and 3) are specified with variables that are commonly used in innovation studies (see e.g. Cohen and Levine 1999 for a survey). These include firm size, market power, competition, human capital, external knowledge sources, capital intensity, firm age and industry dummies. To reduce simultaneity problems, lagged values of the regressors are used whenever possible. Firm size is measured as the logarithm of the number of employees; human capital is proxied by the share of employees with university degree and capital intensity by investment per employee. To account for external knowledge sources two dummy variables are included, taking the value of one if the firm cooperates with other firms or with public scientific institutions respectively.[7] Firm's age is measured in years.

All equations include industry dummies, a year dummy and a variable for firms located in the eastern part of Germany (the former GDR) to account for the transition process. In all specifications seven industry dummies were used. Industries were grouped by (i) R&D intensive manufacturing, (ii) other manufacturing, (iii) knowledge intensive services, (iv) other services, (v) trade, (vi) construction and all (vii) remaining sectors.[8] Market power is measured as the market share computed as the lagged value of a firm's sales relative to total sales on the 3-digit NACE level. In addition, the lagged value of the market entry rate is computed on the 3-digit NACE level, to account for competition. It is defined as the change of the logarithm of the

[7] The survey questions underlying these variables refer to cooperation with firms and institutions in general and not to cooperation on R&D as in CIS innovation surveys. Hence they do not imply but might affect the probability of engaging in R&D as shown by Zimmermann (2004).
[8] The results of the empirical model were robust to a more narrow definition of industries.

number of firms from the current to the previous year. Information about total sector sales and competition is taken from register data.[9]

Recent work on innovation and firm performance often includes variables capturing the effect of engagement in regional and international markets such as an export share or the share of sales that is generated in a specific region (see e.g. Lööf and Heshmati 2006). These are not included in this paper though, because they are likely to be endogenous, too. As they are not available as lagged values, there might be reverse causality from FDI and innovation to engagement in international markets. Furthermore, it is usually found that innovation spurs export activity but exports do not affect innovation (see e.g. Ebling and Janz 1999). However, the estimation results regarding the impact of foreign takeovers were not sensitive to including or excluding these variables.

The innovation literature stresses the importance of internal financial capabilities for financing innovation expenditures (see e.g. Carpenter and Petersen 2002 or Czarnitzki 2006 for recent work on this topic.) The reason is that there is information asymmetry and moral hazard in imperfect financial markets. These problems are probably more severe with regard to R&D expenditure than to tangible investments, because of the highly volatile outcome of R&D. Therefore, two dummy variables representing internal financial capabilities are added to the selection equation. One is a dummy variable that takes the value of one, if the firm has financed part of its tangible investment by equity capital in the past as well as a dummy variable that takes the value of one, if the firm had received public funding since 1997 (regardless of the source and purpose) is included. These variables are expected to be inversely related to a firm's financial constraints and thus are expected to have a positive effect on a firm's innovation decision.

A priori, there are no good reasons to assume that a variable that determines the decision to innovate does not influence the height of expenditures. When running the regression with the same variables in equation (2) and (3) the coefficients for public funding and equity financing where insignificant in the R&D expenditure equation. This is in line with other empirical findings, e.g. Bond et al. (1999) find that cash flow affects the propensity to engage in R&D but not R&D intensity. Hence, these variables were excluded from equation (3). Although the financial variables refer to past behaviour, endogeneity of these variables cannot be completely

[9] The German "Umsatzsteuerstatistik" from the Fedral Bureau of Statistics (Statistisches Bundesamt) is used to gather data on sector sales and competition.

ruled out. But the estimated impact of foreign takeovers was not sensitive to excluding these variables.

A problem that naturally arises in R&D equations is that of double counting (Schankerman 1981). First, R&D expenditures for machinery and equipment can usually not be separated from other investment and physical capital. Second, a major part of R&D expenditures are personal costs, which makes it problematic to include a human capital indicator in the equation determining R&D expenditures as argued by Janz et al. (2004). On the other hand, physical as well as human capital intensity certainly influences the profitability of R&D expenditures. A further problem is the possible endogeneity of a firm's market share (see e.g. Gotschalk and Janz 2001). However, the main results regarding foreign takeovers were not affected when market share, human or physical capital were excluded from the model.

For identification of the foreign ownership equation (equation 1), an exclusion restriction is needed, i.e. a variable that determines the propensity of a foreign takeover and neither the decision to innovate nor R&D intensity. Firm and market characteristics that account for future profitability of target firms probably also determine the profitability of innovation input, so they cannot be excluded from any equation. There is evidence that distance matters for FDI decisions (Blonigen 2005). For manufacturing firms that act in a global network, transport costs might matter in the decision which firm to acquire. Further and maybe more important the (marginal) costs of transmitting tacit knowledge increase with distance (Blanc and Sierra 1999) as well as the cost of monitoring (Degryse and Ongena 2005). In addition, the smaller the distance between investor and potential target firm, the higher is the probability that the investor eliminates a competitor on the same market.

Therefore, a dummy variable for border regions is added to the FDI equation. This is a reasonable proxy for distance since a substantial amount of foreign shareholders (above 50%) is located in Germany's neighbour countries, especially in the Netherlands, Switzerland and Austria (see table 4) and more than 15% are located in countries that have a low distance to Germany such as Sweden, the United Kingdom and Italy.[10] But even investors from overseas may have an incentive to acquire firms in border regions if they also have subsidiaries in neighbour countries. Border regions were identified by merging the firms´ postal codes with county districts. Although there might be regional differences in innovation activities, these

[10] The numbers in the table refer to instances of foreign ownership above ten percent. A firm can have multiple foreign owners that are located in different countries.

should be mainly due to industry and firm size composition. Recent research casts serious doubt that local interactions affect knowledge flows and innovation (see e.g. Marinai and Giuri 2007). Hence it seems reasonable to exclude the border dummy from equations (2) and (3) once we control for market power, industry, size and other firm characteristics. Differences between the eastern and the western part of Germany are still accounted for by a dummy variable in all equations.

The independent variables in the innovation output equation (equation 5) are the same as the determinants of R&D, with two exceptions. The proxy for market power and the variables representing firms´ financial capabilities are excluded. The reasoning is that past market power affects the decision of how much to invest in R&D because of strategic reasons, but strategic interaction should not affect the success of innovation conditional on R&D expenditures. Financial capabilities should only have an indirect effect on innovation output via the amount of R&D expenditures.

5. Results

In table 5 estimation results of simple regressions for innovation activities that do not account for the possible endogeneity of FDI are presented. These results serve as a benchmark for the more sophisticated methods described in the recent section. Column one shows estimation results for the R&D intensity of firms that engage in R&D. In column two the probability of engaging in R&D is estimated by a probit model and column 3 shows estimation of an ordered probit model with known thresholds (interval regression) for the determinants of the share of innovation sales in total sales. It shows that after controlling for standard covariates there is no significant difference regarding R&D intensity between foreign and domestic firms. But foreign-owned firms have a higher share of innovation sales in total sales conditional on R&D intensity. Since there are probably unobserved factors that influence foreign takeovers as well as firm performance and innovation activities these results should only be interpreted as descriptive evidence.

5.1 Innovation input

Table 6 shows the results for estimation of equations (1)-(3), that control for endogeneity and selection bias. The coefficient for foreign takeover is highly significant and negative in the selection equation. The marginal effects is about minus 23 per cent regarding the propensity to spend a positive amount on R&D in the current year.[11] Thus, it seems that foreign firms tend to relocate R&D facilities to their headquarters rather than to stimulate further R&D. An alternative interpretation is that foreign takeovers lead to rationalization and thus to a reduction of R&D activities in target firms. Also, a negative impact can be observed for the R&D intensity given the firm is engaged in R&D. A foreign takeover reduces R&D expenditures per employee by about 60% percent for these firms.[12] The estimated impact is higher as in other empirical studies; e.g. Falk and Falk (2006) estimate a difference of minus 30 to minus 40 per cent. However, they use a cross section where they cannot distinguish between Greenfield investments and foreign takeovers and do not control for unobserved heterogeneity. A further explanation for our findings is that foreign takeovers aim to acquire technologies in target firms rather than to exploit and transfer existing knowledge. This is in line with Grimpe and Hussinger (2007) who argue that mergers and acquisitions are often conducted to avoid competition in technology markets. Interestingly, Frey and Hussinger (2006) show that technological relatedness of acquirer and target is a significant determinant of cross-border deals but does not affect the propensity of domestic deals.

The coefficients for the other variables are plausible. R&D expenditures rise less than proportionally with firm size, while the propensity to perform R&D activities rises with firm size. This contradicts with one of the stylized facts in Cohen and Levine (1989) that states that R&D intensity rises monotonically with firm size, but is not implausible since this result has often been found for Germany (see e.g. Janz, et al. 2004).[13] Both innovation propensity and R&D intensity are positively associated with human capital, physical capital intensity and market power of firms. Firms that cooperate with public institutions or with other firms as well as younger firms are more innovative. As expected, public funding and the dummy for own-resource financing increase the probability of engaging in R&D. As these variables were not significant if they were inserted in equation (3) they are omitted from this equation. The reason for the insignificance is probably that these variables represent rather basic requirements for R&D activities, which usually imply a high minimum size and fixed costs. Competition growth has a positive, but insignificant impact on the propensity to engage in R&D, but has a negative impact on the amount of R&D expenditures. The different sign of the impacts of competition on

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[11] See Greene (1996) for the calculation of marginal effects in the bivariate probit model.

[12] Since the dependent variable logarithmic, the effect is calculated as $(\exp(\delta)-1)\times 100\%$. Where δ is the conditional marginal effect. See Saha et al. (1997) for calculation of marginal effects in selection models.

[13] It is sometimes argued that the relation between firm size and R&D has a U-shaped form, but there was no support for this hypothesis in this application. A possible explanation for this is that the dataset used is restricted to firms with up to 500 million € annual sales.

the decision to perform R&D and the intensity of R&D are plausible, since it is often argued that the relationship between competition and innovation is an inverted U (Aghion et al. 2002). It was also experimented with the lagged market growth rate to control for demand effects, but it was never significant in any of the equations.

Turning to the results for the FDI equation (last column of table 6) we see that the probability of a foreign takeover is as expected significantly higher for firms that are located in border regions. In addition lagged market power is a strong predictor for foreign takeovers while the growth of competition discourages foreign investors. Furthermore, larger firms and firms with a higher skill or capital intensity and younger firms are more likely to be subject to a foreign takeover. The results show high and significant values for the correlation coefficients of the FDI equation and the two R&D equations. This implies that it is necessary to specify the equation system in this way. The positive signs of the correlation coefficients for the FDI equation and the two innovation equations indicate that unobserved factors that increase a firm's innovation effort also increase the probability of a foreign takeover and lead to an upward bias in simple regressions that do not account for the endogeneity of FDI. It seems that foreign investors tend to pick target firms with high unobserved innovation potential, hence the results of simple regressions may be misleading.

The reliability of the results crucially depends on the validity of the exclusion restriction. As the test statistics show the dummy variable for being located in a border region is positive and highly significant in the FDI equation. As discussed in the previous section, it seems reasonable to assume that being located in a border region is not systematically correlated with innovation input once we control for several firm, industry and market characteristics that might differ between regions. A further indicator for the validity of the exclusion restriction is that this variable was not significant if included in the R&D intensity equation or the innovation decision equation.[14]

In Table 7 the selection equation refers to the probability of being engaged in R&D *continuously*. The estimated marginal effect of a foreign acquisition on the probability to be engaged in R&D continuously is about minus 12 per cent. The effect of a foreign takeover on R&D intensity is insignificant if the R&D intensity equation is restricted to firms that are engaged in R&D

[14] This is of course no formal proof, since the model cannot be identified if the exclusion restriction is included in the R&D equations. The R&D equations were estimated separately for FDI firms and domestic firms with the border dummy as regressor.

continuously. A reason for this result is probably that firms with facilities for continuous R&D, which are not completely relocated after the takeover, have a valuable knowledge stock which makes it less feasible to cut R&D activities. It seems that in firms that perform R&D continuously, foreign investors either cut or relocate R&D activities completely or they do not change the extent of R&D expenditures at all. Further, firms that are engaged in R&D continuously might organize their innovation processes more efficiently, thus there might be a lower potential for cost saving in the R&D activities of these firms. The results for the other variables are very similar to those presented in table 6. Because of the simultaneous estimation of the three equations there are minor changes to the coefficients in the FDI equation.

A potential problem of the estimated models is the possible endogeneity of some of the right-hand side variables like market power, cooperation and the firm's skill structure. However, the results for the impact of foreign takeovers where not sensitive to the exclusion of any of these variables. Several other robustness checks were performed. One was to estimate the model only for incorporated companies, since most target firms are incorporated and there is some evidence that research activities might be generally different in managerial owned firms (Czarnitzki and Kraft 2004). Another was to exclude all independent firms from the sample, since there might be a general effect of mergers or belonging to a group of firms (Hall, Bernd and Levine 1990). In both cases the results do not differ remarkably, so the negative coefficient for a foreign takeover does not primarily estimate the effect of belonging to a conglomerate or a certain legal form. The reason not to restrict the analysis to incorporated firms a priori is that legal forms might be changed in advance of a merger or acquisition. Replacing the border dummy with an alternative proxy for distance, the inverse of the distance to border led to very similar results, but this measure is quite imprecise since only air-line distances and not true travel time can be taken into account. Hence, the specification with the border dummy was chosen as the preferred one.

5.2 Innovation output

Due to the cross-sectional character of the data, R&D expenditures and innovation output are observed in the same period and hence the estimation does not allow for a time lag between R&D expenditures and innovation output. But there is evidence that the main part of R&D expenditures is development with a quite short time horizon (Griliches 1998). Therefore, most innovation studies relate innovation output to R&D expenditures in the current year.

Table 8 shows the estimation results for innovation output. Column 1 shows the results for the share of sales from product innovations, columns two and three the results for the binary indicators for product and process innovations. The innovation sales equation is estimated as a linear regression and analogously to the innovation sales equation, the equations for the binary indicators are estimated as a linear probability model. Standard errors are adjusted since the inverses of Mill´s ratios are included together with the predicted latent R&D intensity. The estimated impact of foreign takeovers on innovation sales as well as on the probability of a product or process innovation is insignificant. The positive and partly significant estimates for the inverses of Mill´s ratios imply that there is positive selection of both firms that engage in R&D and foreign-owned firms. This indicates that the estimates for the impact of foreign takeovers on innovation output in the basic specification in table 5 are biased upwards. It seems that not controlling for the endogeneity of R&D causes an upward bias for the estimate of the elasticity of R&D in the basic specification. This seems to outweigh the effect of possible measurement error - e.g. due to the limited ability of small firms to quantify their R&D expenditures - in the R&D variable which would cause a downward bias (Griliches and Mason 1972).

The FDI coefficient is positive for the estimates on the introduction of new products and processes but again insignificant. The estimates of the control variables have the expected sign. R&D intensity, capital intensity and human capital significantly increase innovation output and firms that have access to external knowledge sources, i.e. cooperate with other firms or public institutions are more likely to generate innovations. Due to the qualitative and categorical nature of the innovation output variables and the necessity to perform a linear regression the estimates are quite imprecise. However, the results are robust across the three different measures of innovation output. The impact also remained insignificant if the estimation sample was restricted to firms that report to be engaged in R&D or to perform R&D continuously, but the results were less precise because of the low number of FDI firms that are both engaged in R&D continuously and introduced new products or processes.

All in all, the results suggest that target firms do not benefit from technology spillovers from multinational parents in form of a higher innovation output. Since the estimates are conditional on predicted R&D intensity there is no direct but an indirect effect from foreign takeovers on innovation output. This indirect effect is negative and stems from a reduction in R&D activities since the propensity to perform own R&D activities and the R&D intensity - at least for firms that do not perform R&D continuously - is significantly reduced by a foreign takeover.

6. Conclusion and discussion

Using a unique data set of German firms, that combines survey information on innovation characteristics with ownership information from a balance sheet data base, this paper examines the impact of foreign takeovers on innovation input and output in target firms. After controlling for simultaneity and selection bias as well as for standard covariates such as firm size, industry, market power, external knowledge sources and financial capabilities, the following results emerge. Foreign takeovers seem to have a large and significant negative impact on the propensity to engage in R&D in target firms. Given that a firm performs R&D, a high average negative impact on R&D intensity concerning all firms that are engaged in R&D, but no significant effect on firms that perform R&D continuously was found. The negative impact may result from rationalization and from relocation of R&D activities to foreign headquarters.

A reduction in R&D spending does not necessarily result in decreased welfare in the host country if rationalization of R&D leads to an increase in efficiency. However, conditional on R&D expenditures no significant impact of foreign takeovers on innovation output was found in the short run. Furthermore, the estimation results suggest that there is an indirect negative effect via reduced R&D activities. The results imply that expectations regarding positive impacts of foreign direct investment on local target firms should be scaled down. Further, the results imply that national R&D policy should concentrate on enhancing firms´ continuous R&D activities to make firms capable of competing in international markets and reduce the risk of R&D relocation in case of a takeover.

The main caveats of this study are the short time horizon and the discrete measurement of innovation output. On the one hand, restructuring by foreign-owned firms might take some time, until the target firm benefits from spillovers from the multinational parent. On the other hand, since innovation activities can act as an indicator for the future performance of firms this might be a minor problem of this study. In the current data set there is no continuous measure of innovation output. Further, there is only a discrete measure for process innovations, but no indicator for the success of process innovations analogously to the share of sales from product innovations. Nonetheless, since the estimated impact of FDI was not significant across three different measures of innovation output, the results suggest that target firms do not benefit from technology transfer in form of a higher innovation output.

The results of this paper highlight the importance of selectivity and endogeneity in analyzing the impacts of FDI and raise concerns that cross-border mergers and acquisitions are detrimental to technological progress in the host country. The possible negative effects on innovation activities should be taken into account when the welfare effects of FDI are evaluated, but the results should not be taken as evidence that FDI only has negative effects for the host country. Greenfield investments in contrast to foreign takeovers may induce positive effects via increased competition as the results of previous empirical studies indicate (Bertschek 1995, Blind and Jungmittag 2004).

It might be interesting to decompose the average effect of inward FDI to the degree of ownership (i.e. minority, majority or wholly owned) and to the type of investment, e.g. vertical versus horizontal FDI and financial investors versus industrial companies. In the sample used in this paper, the small number of foreign takeovers makes it infeasible to split the sample further and get reliable results. Future research should also account for the time series aspect in the innovation process by differentiating between short and long run effects of foreign takeovers and allow for a time lag in the impact of R&D spending and ownership change on innovation output.

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Table1: Mean values of variables for foreign-owned firms and domestic firms

Variable	Description	Foreign-owned firms	Domestic firms
Log R&D intensity	Logarithm of R&D expenditures per employee	3.918	2.213
R&D/sales	R&D expenditures as a share of total sales in %	3.938	1.975
Innovation sales	Share of sales from product innovations in total sales in %	42.315	33.960
Non-zero R&D	=1 if positive R&D expenditures reported	0.431	0.246
Continuous R&D	=1 if firm was engaged in R&D on a permanent basis in the last 3 years	0.284	0.131
Product innovation	=1 if product innovation in the last 3 years	0.569	0.417
Process innovation	=1 if process innovation in the last 3 years	0.428	0.314
Log size	Logarithm of number of employees	3.409	2.916
Size	Number of employees	89.674	47.212
Employment growth	Two year employment growth rate	-0.007	-0.028
Productivity	Sales per employee in 1000€	297.055	264.391
Sales growth	One year sales growth rate	0.026	0.015
Log capital intensity	Logarithm of tangible investment per employee	7.032	5.686
Share high skilled	Share of employees with university degree in %	34.364	25.268
Cooperation firms	=1 if firm cooperates with other firms	0.266	0.229
Cooperation science	=1 if firm cooperates with public scientific institutions	0.147	0.068
Log firm age	Logarithm of firm age in years	2.874	3.094
Log Market share	Logarithm of sales relative to total sales on 3 -digit NACE level in %	-4.042	-5.124
Competition growth	Entry/exit rate on 3-digit NACE level in %	-0.387	-0.420
Equity finance	=1 if firm has financed part of its tangible investment by equity	0.641	0.516
Public funding	=1 if firm has received public funding	0.592	0.627
East Germany	=1 if firm is located in the former GDR	0.417	0.441
Border	=1 if firm is located in a border region	0.206	0.148

Table 2: Distribution of foreign-owned firms across industries

Industrial Classification	% of foreign-owned firms
R&D intensive manufacturing	5.51
Other Manufacturing	3.62
Construction	2.73
Trade	1.85
Knowledge intensive services	2.87
Other Services	2.32
Others	1.12
All	2.11

Table 3: Size distribution of foreign-owned firms

Number of employees	% of foreign-owned firms in size class
<5	1.10
5-9	1.75
10-19	1.75
20-49	2.66
50-99	2.12
100-249	4.07
250-499	2.29
>=500	8.11

Table 4: Distribution of the origin of foreign ownership

Country	Share of all foreign owners in %
Austria	11.29
Belgium	4.52
Denmark	3.29
France	6.16
Italy	5.13
Luxembourg	3.29
Netherlands	13.35
Sweden	3.08
Switzerland	12.24
United Kingdom	7.39
United States	11.7
All other countries	18.56 (each country < 2%)

Table 5: Simple regressions for innovation activities

Dependent Variable	*Log R&D intensity*	*Non-zero R&D*	*Innovation sales*
Estimation method	OLS	Probit	Ordered Probit (Known Thresholds)
FDI	0.141 (0.124)	0.161 (0.107)	4.995*** (1.812)
Log R&D intensity			1.554*** (0.083)
Log size	-0.394*** (0.026)	0.043** (0.018)	-0.828*** (0.284)
Share high skilled	0.002** (0.001)	0.002*** (0.001)	0.031*** (0.010)
Log capital intensity	0.022** (0.009)	0.016** (0.006)	0.270*** (0.098)
Cooperation firms	0.008 (0.054)	0.319*** (0.042)	1.478** (0.674)
Cooperation science	0.259*** (0.064)	1.205*** (0.071)	1.171 (1.171)
Log firm age	-0.106*** (0.031)	-0.077*** (0.022)	-4.138*** (0.332)
East Germany	-0.308*** (0.061)	-0.275*** (0.045)	-2.125*** (0.68)
Equity finance	0.073 (0.073)	0.052*** (0.052)	-0.448 (0.804)
Public funding	-0.066 (0.060)	0.193*** (0.039)	0.428 (0.583)
Log market share	0.174*** (0.018)	0.083*** (0.013)	0.009 (0.209)
Competition growth	-0.014* (0.008)	0.009 (0.006)	0.053 (0.102)
Log-Likelihood		-3182.727	-12224.812
F Test / LR test (p-value)	25.43 (0.000)	1793.00 (0.000)	946.82 (0.000)
(Pseudo-) R^2	0.207	0.220	
No. observations	1872	7040	6970

Notes: Standard errors are shown in parentheses. *** (**, *) denotes significance at the 1% (5%, 10%) level. All regressions include industry and time dummies.

Table 6: Maximum likelihood estimation for selection of firms engaged in R&D

	Log R&D intensity	*Non-zero R&D*	*FDI*
FDI	-1.385*** (0.199)	-0.960*** (0.290)	
Log size	-0.375*** (0.028)	0.044** (0.018)	0.045 (0.032)
Share high skilled	0.003*** (0.001)	0.002*** (0.001)	0.004*** (0.001)
Log capital intensity	0.022*** (0.008)	0.017*** (0.006)	0.019** (0.009)
Cooperation firms	0.003 (0.066)	0.313*** (0.041)	
Cooperation science	0.301** (0.129)	1.179*** (0.072)	
Log firm age	-0.163*** (0.036)	-0.089*** (0.022)	-0.188*** (0.042)
East Germany	-0.397*** (0.070)	-0.293*** (0.045)	-0.281*** (0.080)
Border Region			0.264*** (0.079)
Equity finance		0.137*** (0.051)	
Public funding		0.191*** (0.038)	
Log market share	0.201*** (0.022)	0.091*** (0.013)	0.118*** (0.024)
Competition growth	-0.020** (0.009)	0.007 (0.006)	-0.023** (0.011)
ρ_{12}		0.124 (0.170)	
ρ_{u2}		0.675*** (0.059)	
ρ_{u1}		0.530*** (0.116)	
σ		1.171*** (0.030)	
Log-Likelihood		-6756.37	
Wald-Test (p-value)		452.64 (0.000)	
No. observations		7040 (1874 uncensored)	

Notes: Standard errors are shown in parentheses. *** (**, *) denotes significance at the 1% (5%, 10%) level. All equations include industry and time dummies.

Table 7: Maximum likelihood estimation for selection of firms with continuous R&D

	Log R&D intensity	*Continuous R&D*	*FDI*
FDI	0.367 (0.315)	-0.844** (0.378)	
Log size	-0.361*** (0.036)	0.047** (0.021)	0.035 (0.034)
Share high skilled	0.004*** (0.001)	0.004*** (0.001)	0.004*** (0.001)
Log capital intensity	0.033*** (0.010)	0.008 (0.008)	0.022** (0.009)
Cooperation firms	0.002 (0.082)	0.310*** (0.046)	
Cooperation science	0.309** (0.128)	0.910*** (0.066)	
Log firm age	-0.166*** (0.045)	-0.106*** (0.026)	-0.176*** (0.042)
East Germany	-0.423*** (0.09)	-0.367*** (0.052)	-0.258*** (0.083)
Border Region			0.226*** (0.085)
Equity finance		0.165*** (0.06)	
Public funding		0.226*** (0.046)	
Log market share	0.127*** (0.026)	0.110*** (0.016)	0.116*** (0.024)
Competition growth	-0.006 (0.01)	0.003 (0.007)	-0.023** (0.011)
ρ_{12}		0.166 (0.136)	
ρ_{u2}		-0.137 (0.130)	
ρ_{u1}		0.510*** (0.175)	
σ		1.093*** (0.035)	
Log-Likelihood		-4487.60	
Wald-Test (p-value)		262.11 (0.000)	
No. observations		7040 (1004 uncensored)	

Notes: Standard errors are shown in parentheses.*** (**, *) denotes significance at the 1% (5%, 10%) level. All equations include industry and time dummies.

Table 8: Innovation output

	Innovation sales	*Product innovation* (0/1)	*Process innovation* (0/1)
FDI	-0.221 (0.429)	0.163 (0.153)	0.076 (0.184)
Log R&D intensity	0.102* (0.055)	0.086*** (0.022)	0.050** (0.023)
Log size	0.013 (0.019)	0.041*** (0.007)	0.067*** (0.007)
Share high skilled	0.002*** (0.001)	0.001*** (0.000)	0.000 (0.000)
Log capital intensity	0.017*** (0.003)	0.012*** (0.001)	0.012*** (0.002)
Cooperation firms	0.139*** (0.028)	0.093*** (0.013)	0.082*** (0.014)
Cooperation science	0.286*** (0.054)	0.196*** (0.022)	0.117*** (0.023)
Log firm age	-0.165*** (0.019)	0.010 (0.007)	-0.010 (0.007)
East Germany	-0.113*** (0.039)	-0.046*** (0.016)	-0.067*** (0.016)
Competition growth	0.003 (0.005)	0.003* (0.002)	0.001 (0.002)
λ_{FDI}	0.269 (0.197)	0.011 (0.069)	0.012 (0.081)
$\lambda_{R\&D}$	0.384*** (0.023)	0.259*** (0.010)	0.142*** (0.012)
R^2	0.131	0.249	0.144
Wald-Test (p-value)	1436.54 (0.000)	2958.28 (0.000)	1165.64 (0.000)
No. observations	7040	6849	6775

Notes: Bootstrapped standard errors are shown in parentheses. *** (**, *) denotes significance at the 1% (5%, 10%) level. All regressions include industry and time dummies.

Appendix

1. Maximum Likelihood estimation

The log likelihood function for the bivariate selection model consists of four different parts depending on the values of *I* and *FDI*

$$\ln L_i = \begin{cases} \ln\left(\Phi_{(2)}\left[-x_{1i}^{'}\beta_1, -w_i^{'}\gamma, \rho_{u1}\right]\right) & \text{if } I=0 \,\&\, FDI=0 \\ \ln\left(\Phi_{(2)}\left[-x_{1i}^{'}\beta_1, w_i^{'}\gamma, -\rho_{u1}\right]\right) & \text{if } I=0 \,\&\, FDI=1 \\ \ln\left(\Phi_{(2)}\left[\eta_I, \eta_{FDI}, \rho_{u1}\right]\right) - \frac{1}{2}\ln(2\pi) - \ln\left(\sigma_{\varepsilon_2}\right) - \frac{1}{2}\left(\frac{RD_i - x_{2i}^{'}\beta_2 - \delta_2 FDI}{\sigma_{\varepsilon_2}}\right)^2 & \text{if } I=1 \,\&\, FDI=1 \\ \ln\left(\Phi_{(2)}\left[\eta_I, -\eta_{FDI}, -\rho_{u1}\right]\right) - \frac{1}{2}\ln(2\pi) - \ln\left(\sigma_{\varepsilon_2}\right) - \frac{1}{2}\left(\frac{RD_i - x_{2i}^{'}\beta_2 - \delta_2 FDI}{\sigma_{\varepsilon_2}}\right)^2 & \text{if } I=1 \,\&\, FDI=0 \end{cases}$$

$$\text{where } \eta_I = \left(x_{1i}^{'}\beta_1 + \rho_{12}\frac{x_{2i}^{'}\beta_2 + \delta_2 FDI_i}{\sigma_{\varepsilon_2}}\right)\frac{1}{\sqrt{1-\rho_{12}^{\;2}}}$$

$$\eta_{FDI} = \left(w_i^{'}\gamma + \rho_{u2}\frac{x_{2i}^{'}\beta_2 + \delta_2 FDI_i}{\sigma_{\varepsilon_2}}\right)\frac{1}{\sqrt{1-\rho_{u2}^{\;2}}}$$

2. Inverses of Mill´s ratios for bivariate distribution

For the bivariate selection model, the expressions for inverses of Mill´s ratios are defined as follows (see Goux and Maurin, 2000, Reize, 2001 or Reize, 2004b):

$$\lambda_{RD} = \frac{\phi\left(x_{1i}^{'}\beta_1\right)\Phi\left(\left(w_i^{'}\gamma - \rho_{u1}(x_{1i}^{'}\beta_1 + \delta_1 FDI_i)\right)\frac{1}{\sqrt{1-\rho_{u1}^{\;2}}}\right)}{\Phi_{(2)}\left[x_{1i}^{'}\beta_1 + \delta_1 FDI_i, w_i^{'}\gamma, \rho_{u1}\right]}$$

if *FDI* =1 & *I*=1

$$\lambda_{FDI} = \frac{\phi\left(w_i^{'}\gamma\right)\Phi\left(\left(x_{1i}^{'}\beta_1 + \delta_1 FDI_i - \rho_{u1}w_i^{'}\gamma\right)\frac{1}{\sqrt{1-\rho_{u1}^{\;2}}}\right)}{\Phi_{(2)}\left[x_{1i}^{'}\beta_1 + \delta_1 FDI_i, w_i^{'}\gamma, \rho_{u1}\right]}$$

$$\lambda_{RD}=\frac{\phi\left(x_{1i}^{'}\beta_1\right)\Phi\left(\left(-w_i^{'}\gamma+\rho_{u1}(x_{1i}^{'}\beta_1+\delta_1 FDI_i)\right)\frac{1}{\sqrt{1-\rho_{u1}^{\ 2}}}\right)}{\Phi_{(2)}\left[x_{1i}^{'}\beta_1+\delta_1 FDI_i,-w_i^{'}\gamma,-\rho_{u1}\right]}$$

if FDI =0 & I=1

$$\lambda_{FDI}=\frac{-\phi\left(w_i^{'}\gamma\right)\Phi\left(\left(x_{1i}^{'}\beta_1+\delta_1 FDI_i-\rho_{u1}w_i^{'}\gamma\right)\frac{1}{\sqrt{1-\rho_{u1}^{\ 2}}}\right)}{\Phi_{(2)}\left[x_{1i}^{'}\beta_1+\delta_1 FDI_i,-w_i^{'}\gamma,-\rho_{u1}\right]}$$

$$\lambda_{RD}=\frac{-\phi\left(x_{1i}^{'}\beta_1\right)\Phi\left(\left(w_i^{'}\gamma-\rho_{u1}(x_{1i}^{'}\beta_1+\delta_1 FDI_i)\right)\frac{1}{\sqrt{1-\rho_{u1}^{\ 2}}}\right)}{\Phi_{(2)}\left[-(x_{1i}^{'}\beta_1+\delta_1 FDI_i),w_i^{'}\gamma,-\rho_{u1}\right]}$$

if FDI =1 & I=0

$$\lambda_{FDI}=\frac{\phi\left(w_i^{'}\gamma\right)\Phi\left(\left(-(x_{1i}^{'}\beta_1+\delta_1 FDI_i)+\rho_{u1}w_i^{'}\gamma\right)\frac{1}{\sqrt{1-\rho_{u1}^{\ 2}}}\right)}{\Phi_{(2)}\left[-(x_{1i}^{'}\beta_1+\delta_1 FDI_i),w_i^{'}\gamma,-\rho_{u1}\right]}$$

$$\lambda_{RD}=\frac{-\phi\left(x_{1i}^{'}\beta_1\right)\Phi\left(\left(-w_i^{'}\gamma+\rho_{u1}(x_{1i}^{'}\beta_1+\delta_1 FDI_i)\right)\frac{1}{\sqrt{1-\rho_{u1}^{\ 2}}}\right)}{\Phi_{(2)}\left[-(x_{1i}^{'}\beta_1+\delta_1 FDI_i),-w_i^{'}\gamma,\rho_{u1}\right]}$$

if FDI =0 & I=0

$$\lambda_{FDI}=\frac{-\phi\left(w_i^{'}\gamma\right)\Phi\left(\left(-(x_{1i}^{'}\beta_1+\delta_1 FDI_i)+\rho_{u1}w_i^{'}\gamma\right)\frac{1}{\sqrt{1-\rho_{u1}^{\ 2}}}\right)}{\Phi_{(2)}\left[-(x_{1i}^{'}\beta_1+\delta_1 FDI_i),-w_i^{'}\gamma,\rho_{u1}\right]}$$