Financing and Internationalization of R&D Intensive Firms

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Contents

Preface **1**

1 Measurement and Determinants of Access to Credit **7**

1.1 Introduction 7

1.2 Data and Methodology 11

1.2.1 Data 11

1.2.2 Measuring Access to Credit 13

1.2.3 Regression Strategy 15

1.2.4 Explanatory Variables 18

1.2.5 Descriptive Statistics 24

1.3 Results 26

1.3.1 Access to Credit 26

1.3.2 Usage of Credit 29

1.3.3 Perception-based Indicator 31

1.4 Sensitivity Analysis 34

1.4.1 Alternative Exclusion Restrictions 34

1.4.2 Assumption of Joint Normality 35

1.4.3 Standard Errors Clustered on Industry-Country-Level 36

1.5 Conclusions 36

2 Patents in the Financing of R&D Intensive Start-up Firms: Evidence from Germany **39**

2.1 Introduction 39

2.2 Related Literature 43

2.3 Data . . . 46
2.3.1 Measuring Access to Finance . . . 47
2.3.2 Measuring Patenting Activities . . . 50
2.4 Empirical Approach . . . 54
2.5 Results . . . 57
2.5.1 Patent Functions . . . 57
2.5.2 Patents in External Financing . . . 60
2.6 Robustness Checks . . . 64
2.6.1 Nonlinear Estimations of Patent Functions . . . 64
2.6.2 3SLS Estimations . . . 66
2.7 Conclusions . . . 67

3 Global Investment Decisions and Patent Protection: Evidence from German Multinationals 69

3.1 Introduction . . . 69
3.2 Empirical Specification . . . 74
3.2.1 Identification . . . 74
3.2.2 Estimating Equations . . . 77
3.3 Data . . . 79
3.3.1 Patent Protection Across Countries . . . 79
3.3.2 Sensitivity to Patent Protection Across Sectors . . . 80
3.3.3 German Outward FDI . . . 81
3.4 Results . . . 84
3.4.1 Location Decision . . . 84
3.4.2 Size of Investment . . . 86
3.4.3 Ownership Structure . . . 88
3.5 Sensitivity Analysis . . . 91
3.5.1 Estimation with Country-Year Fixed Effects . . . 91
3.5.2 Identification of Patent Reforms . . . 91
3.5.3 Alternative Measurement of IPR Protection . . . 92
3.5.4 Nonlinear Estimation of the Location Decision . . . 93

3.6 Conclusions 94

Appendices **96**

A Appendix to Chapter 1 97

B Appendix to Chapter 2 102

C Appendix to Chapter 3 107

List of Figures **118**

List of Tables **119**

Bibliography **121**

Preface

Knowledge and knowledge-based value creation processes play an increasing role in modern economies. In the last two decades investments in knowledge have gained importance relative to investments in physical assets. The OECD reports that private and public investments in knowledge as percentage of GDP have increased by 0.7 percentage points in OECD countries during the years 1997-2004. At the same time, investments in physical assets such as machinery and equipment have decreased by 1.1 percentage points.[1] The increasing importance of intangible assets in the value creation process presents a significant challenge for innovation policies in knowledge-based economies. Innovative firms that intensely invest in research and development (R&D) highly rely on intangible assets and are faced with serious market failures. These frictions can restrict R&D intensive firms' innovation and internationalization activities and are expected to hamper overall technological progress and economic growth.

Imperfect financial markets that are characterized by information asymmetries can restrict the access to finance for R&D intensive start-up firms. These firms have only short track records and due to their focus on R&D, they have only few tangible assets that can be used as collateral for financial investors. Thus, financial frictions are particularly severe for new firms and firms undertaking innovative activities (Hall and Lerner, 2009).[2] At the same time, young and small firms significantly contribute to technological progress and economic growth (OECD, 2013). Financial constraints restrain the innovation activities

[1] Investments in knowledge are defined as expenditures on research and development, higher education and software. See OECD (2007) for further details.

[2] See, e.g., Aghion et al. (2007), Brown et al. (2009a).

of these firms and result in an overall decelerated rate of innovation and a slowdown in economic progress.[3]

Further, R&D intensive firms additionally face the problem that their created knowledge exhibits the characteristics of public goods. Once information on inventions is revealed, the knowledge is non-rival and non-excludable. A sufficient patent protection is necessary to maintain investment incentives and to overcome problems of underinvestment. In their internationalization strategy, R&D intensive firms have to consider that patent law is a territorial concept, i.e., the scope of patent protection is limited to the territory of the country where the right is granted. The foundation of a foreign affiliate represents a transaction, whereby sensitive knowledge is transferred outside the firm and intangible assets are exposed to a high risk of infringement. A lacking or insufficient patent protection in host countries can distort global investment decisions and prevent profitable projects. Particularly R&D intensive multinational firms that intensely rely on intangible assets are expected to be highly affected by these frictions. Distorted investments could adversely affect a firm's growth and restrict the technological progress in host countries.

This dissertation attempts to shed more light onto these market imperfections, which are aggravated by firms' reliance on intangible assets and are expected to adversely affect firms' innovation and internationalization strategy. The first two chapters deal with frictions in financial markets. Chapter 1 takes a step back and investigates how access to finance can be precisely measured. A precise measurement is essential to design effective policy measures in order to foster access to finance. On the basis of these findings, Chapter 2 considers the access to external finance of R&D intensive start-up firms and empirically investigates whether patents can mitigate financial frictions of these innovative firms. The third chapter considers frictions in the internationalization strategies of R&D intensive firms. It empirically investigates, whether a strengthening of national patent law affects the global investment decision of multinationals and encourages foreign direct investment.

The first chapter is concerned with the empirical methodology of measuring access to finance. Measuring and identifying financial constraints represents an important challenge in empirical studies. Due to data limitations, access to finance has often been

[3]See, e.g., Savignac (2008), Paunov (2012), Gorodnichenko and Schnitzer (2013), Amore et al. (2013).

approximated by the usage of finance or by perception-based indicators. However, these types of measures disregard firm-specific differences in the demand for external finance. Firms that do not use external finance can either be financially constrained or might have no demand for external finance. Similarly, firms reporting that they do not face problems with access to finance may either have sufficient access or may have no financial demand.

Using unique firm-level survey data which provides information on a firm's demand for credit, we develop a direct measure of access to credit. This measure takes into account whether a firm that has credit demand is successful in obtaining access to credit. In the first part of the analysis, we use our direct measure to estimate the determinants of access to credit. Thereby, we can separate the determinants affecting credit demand from those affecting access. In the second part, we estimate the determinants affecting the usage of credit and the perceived access respectively. A comparison of the identified determinants with those from the access estimation reveals whether the approximating measures allow for a precise identification of credit constraints.

We find that the usage of credit is not adequate to identify financially constrained firms, since the determinants of demand and the determinants of access are not disentangled in the usage measure. Perception based indicators, however, are found to be surprisingly precise, even when information on demand is not available. Based on these findings, recommendations for future survey design for investigating access to finance are drawn. Our results imply that including questions on the demand for external finance is essential to identify access to finance. Further, since firms can be discouraged from applying, information on the application for finance is not sufficient and reasons for why firms have not applied for external finance should be additionally considered.

We contribute to the literature by evaluating whether the usage of credit is a suitable approximation for access to credit and whether perception-based indicators provide precise measurements of credit constraints. To the best of our knowledge, this is the first empirical evaluation of these measures. A precise measure of access to finance is essential for drawing correct policy recommendations from economic research and to design efficient policy measures with the aim of fostering access to finance.

The second chapter turns to the financing of R&D intensive start-up firms. It investigates the role of patents in their external finance and examines whether patents can improve the access to external financing for innovative start-up firms. Patents have the potential to reduce information asymmetries between patentees and investors (Long, 2002) and can also be seen as a type of property rights, since patents are fully transferable as well as exclusive and binding against third parties (Davies, 2006).

Using detailed firm-level survey data of German start-up firms, we identify a firm's financial demand for venture capital and bank financing and investigate whether a firm that has demand for a particular source of finance is successful in obtaining it. To measure a firm's patenting activity and to distinguish high valuable patents, we use value-weighted patent counts that are based on the direct valuations by the patent owners. Instrumental-variable estimations take into account the potential endogeneity of patenting and establish a causal effect of patents.

The analysis reveals two important findings. First, we find strong evidence for its endogeneity and provide a possible instrumentation strategy for patenting. Ignoring the endogeneity of patenting can result in highly biased estimates. Second, our results indicate that patenting significantly increases the probability of using venture capital and bank financing, especially when the values of patents are considered. However, it is not clear whether an increase in the usage of external finance can be fully attributed to an improved access to finance or whether part of the increase is due to an increased financial demand of patenting firms. Using separate measures for demand and access, we can clearly identify a demand driven effect of patents. Patenting firms have a significantly higher demand for external finance, while, after controlling for financial demand, no effect on access to external finance has been found.

The contribution of the second chapter is primarily methodical. For future research on the financial role of patents, our findings emphasize the importance of considering endogeneity issues of patenting and controlling for firm-specific differences in financial demand. We can show that a large part of the increase in the usage of external finance can be attributed to a significantly higher financial demand of patenting firms. This leads to the question, whether the findings in the previous literature on the usage of

external finance can be fully attributed to a signaling effect of patents or whether the identified effect is driven by a higher financial demand of patenting firms. Further, most previous studies on the role of patents in financing have not considered issues of endogeneity.[4] Taking into account our results, it is not clear whether previous findings can be interpreted as causal effects or mere correlations.

The third chapter deals with frictions due to a lack of patent protection and empirically investigates the role of patent protection in the global investment decisions of German multinationals. Using a firm-level panel dataset on the universe of German outward foreign direct investment (FDI), we investigate individual firm-level investment decisions at the extensive and intensive margin of FDI. At the extensive margin, we explore the impact of patent protection on the decision where to locate a foreign affiliate. At the intensive margin, we analyze how the strengthening of patent rights affects the size of the established affiliates and the ownership share held in the foreign affiliates. To isolate the effect of patent protection, we exploit variation of patent protection across countries and time, as well as variation of the dependency on patent protection across sectors and time. A firm's dependency on patent protection is approximated by sector-specific measures of R&D intensity and the perceived effectiveness of patent protection for protecting innovation. By conditioning on an extensive set of fixed effects, we account for unobserved firm- and country-specific heterogeneity and capture potential omitted variable bias.

We find that patent protection affects German foreign direct investment in different ways. Strengthening patent protection positively affects the location decision of German multinationals. Furthermore, we find significant nonlinear effects in a host country's initial legal and economic development. With regard to the intensive margin, we find some evidence for a positive effect of patent protection. However, the effect is much weaker than for the location decision. For the ownership shares held in foreign affiliates, we find that average ownership shares increase significantly after strengthening patent protection.

The analysis complements and contributes to the previous literature on the relation between intellectual property right (IPR) protection and FDI in different manners.

[4] An important exception is the study by Conti et al. (2013).

It provides the first firm-level evidence on German multinationals. Insights into how German multinationals are affected by international patent protection are particularly interesting, since Germany is second in the ranking of FDI outward countries (UNCTAD, 2011). Further, the analysis provides a strong identification strategy that allows for nonlinear effects of patent protection and considers various sources of omitted variable bias. Additionally, we take into account host countries' previous levels of legal and economic development, which enables us to draw more precise policy recommendations for reforming countries. Finally, the analysis provides a comprehensive firm-level analysis of FDI decisions at various levels of FDI, something which has been missing in previous research.

Chapter 1

Measurement and Determinants of Access to Credit*

1.1 Introduction

Access to finance is regarded as a major determinant of economic growth and development and has been an important policy goal for developing countries.[1] During the recent financial crisis bank lending has decreased often dramatically. The resulting credit crunches forced firms to cut their investments (e.g., Campello et al., 2010) and had negative impacts on economic growth. To contain these adverse effects governments took a variety of measures to improve the access to credit for firms, including the provision of public guarantees for loans to particular industries (OECD, 2011). In order to answer the question of how policy measures should be best designed to foster access to finance, a precise measurement of access to finance is necessary. Due to data limitations, direct measurements of access to finance are, in many cases, not available and thus indirect proxies have to be used. Access to finance is often approximated by the usage of finance. This approach, however, neglects the fact that firms that do not use external finance can

*This chapter is based on joint work with Christa Hainz.

[1]E.g., Rajan and Zingales (1998); Beck et al. (2000). For developing countries, there are several studies that use either policy changes or controlled experiments to estimate the effect of credit constraints on firm performance (for a survey, see Beck and Demirgüç-Kunt, 2008). Karlan and Morduch (2009) provide a comprehensive overview on the topic in the context of development economics.

either be financially constrained or might have no demand for external finance. The same is true for perception-based indicators: firms reporting that they do not face problems with access to finance may either have sufficient access or may have no financial demand.

In the paper we develop a direct measure of access to credit, which takes into account whether a firm that has credit demand is successful in getting access to credit. For the first time to our knowledge, this paper then provides an empirical evaluation of measurements that approximate access to credit. To this end it addresses the following questions: what are the determinants of access to credit? Are measurements based on the usage of credit valid approximations for access to credit? Do perception-based indicators allow for precise identification and prediction of credit constraints?

To answer these questions we use the Business Environment and Enterprise Performance Survey (BEEPS), which has been jointly conducted by the European Bank for Reconstruction and Development and the World Bank. This data set contains detailed firm-level survey data for 9,655 firms in 27 countries in Europe and Central Asia. It provides a unique source of financial information on credit financing, which is an important source of external finance for small- and medium enterprises (SME) in general, and for firms in developing countries in particular.

In the survey firms were asked not only whether they have a bank loan, but also to state the reasons why they do not use loans. The answers can be broadly divided into two categories - either a firm was restricted from access to credit or it did not have any demand for it. In a first step, we develop a direct measure of access to credit, which takes into account whether a firm that needs credit is successful in obtaining a loan. By controlling for demand, we can differentiate between firms that are denied access and firms that do not need credit. For the purpose of analyzing access to credit only the first group is relevant. We additionally control for a possible selection bias, as the selection into credit demand might not be random. This allows us to consistently estimate the determinants of access to credit. In a second step, we estimate the determinants for the usage of credit and compare them with the results from the access estimations. Thereby we can highlight the differences between both measures and evaluate whether information on the usage of loans is sufficient to identify credit constraints. Finally, we investigate

whether a perception-based indicator is precise enough to identify the same determinants as a direct measure of access to credit.

Our analysis yields three important results. First, for estimating the determinants of access to credit, we use a two-stage regression for demand and access, so that we can separate the determinants influencing demand from those affecting access. With regard to credit demand, we find a higher demand for domestic firms and firms perceiving competition as more intense. Small firms as well as foreign- and state-owned firms less often demand credit. Given that a firm has demand, a significantly higher probability for access to credit is found for profitable, transparent and foreign-owned firms, while young and small firms face a higher risk of being credit constrained. With regard to country-level characteristics, in particular stronger creditor rights are associated with better access to credit. Second, we estimate the determinants for the usage of credit and compare the identified determinants with those of the access estimations. Our findings reveal considerable differences between both measures and suggest that the demand and the access effect are not disentangled in the usage-approach. We conclude that approximating access to credit by usage of credit is not adequate to identify credit constraints. Third, evaluating the perception-based indicators, we find that these measures can predict credit constraints very precisely, even when information on credit demand is not available.

This paper is related to the literature on access to finance and how it is determined by firm- and country-specific characteristics. In this literature, a variety of measurements for access to finance have been used.[2] Basically, the financial situation of firms has been evaluated by using balance-sheet data or survey data. Balance-sheet data provide information about which sources of finance are actually used and to what extent. Information from the annual report can indicate that financial constraints exist when firms cannot fulfill covenants. Furthermore, balance-sheet data have been used to analyze the sensitivity of investment to cash flows as an indicator of financial constraints (Fazzari et al., 1988). However, there is a considerable debate about this approach (Kaplan and Zingales, 1997, 2000). Since reliable balance-sheet data are needed, these measures are most appropriate for studying large firms. If the research interest concerns SME or firms

[2] A detailed survey of approaches to measure financial frictions can be found in Gumpert (2012).

from developing countries or emerging markets, comprehensive data on balance-sheet information is often not available.

A large strand of the literature on the determinants of access to finance is based on survey data. Often, approximations based on the usage of finance or perception-based indicators for access to finance and cost of finance are used. Beck et al. (2006) show that perceived access is influenced by size, age and ownership of a firm. Brown et al. (2009b) provide evidence that information sharing among banks improves the perceived availability and cost of credit and increases the usage of external finance (in terms of firm debt relative to total assets), particularly for opaque firms and firms located in countries with a weak institutional environment. With respect to institutions, Safavian and Sharma (2007) find that the quality of the legal system and its enforcement are complements, using the usage of loans as dependent variable (as binary variable or as the share of new investments financed through loans). Giannetti and Ongena (2009) show that better financial integration in terms of foreign bank lending increases the usage of credit financing. At the same time, an increased foreign bank presence leads to a higher growth rate among firms. This indirectly indicates that the demand for external finance has also been raised. To summarize, it is not always clear whether an overall increase in the usage of external finance or better perceived access goes along with actually improved access to finance, when the demand for external finance has not been captured.

A small number of papers, which also use the detailed financial information from the BEEPS dataset, consider credit demand in investigating access to credit. Muravyev et al. (2009) explain loan acceptance and control for loan applications in a robustness check, showing that female owners are less likely to obtain loans than male owners. The analysis by Brown et al. (2011) provides a comprehensive examination of the firm and country characteristics that influence whether a firm needs a loan, applies for it and is successful with its application. Popov and Udell (2012) show that the financial health of banks influences the loan supply for firms.

We contribute to the literature by evaluating whether the usage of credit is a suitable approximation for access to credit and whether perception-based indicators provide a precise measurement of credit constraints. A precise measure of access to finance is

essential for subsequent research on the impact of financial constraints on economic outcomes or firm decisions. For instance, financial constraints can affect firm growth and performance (e.g., Beck and Demirgüç-Kunt, 2008) and innovative activities (e.g., Gorodnichenko and Schnitzer, 2013) as well as firm decisions with regard to internationalization (e.g., Berman and Héricourt, 2010; Manova, 2013). Consequently, a precise identification of financially constrained firms is essential to draw policy recommendations and to design efficient policy measures to foster the access to finance.

The paper is organized as follows: Section 1.2 describes the data and the econometric specification. The results of the empirical analysis on the determinants of access to credit are summarized in Section 1.3.1. The evaluation of the usage and perception-based measures are presented in the Sections 1.3.2 and 1.3.3. Section 1.4 presents the sensitivity analysis. This is followed by some conclusions and recommendations for future survey design in Section 1.5.

1.2 Data and Methodology

1.2.1 Data

We use the Business Environment and Enterprise Performance Survey (BEEPS) collected jointly by the World Bank and the European Bank for Reconstruction and Development. The BEEPS assesses the environment for private enterprises and business development. The survey conducted in March and April 2005 entails the most detailed information on debt financing among all waves and thereby enables us to develop a direct measure of access to credit.[3] It covers 27 countries in Eastern Europe and Central Asia. Depending on the size of the country, between 200 and 900 firms were interviewed. We exclude data

[3]Only the BEEPS 2005 wave provides information on the usage of credit and credit applications that both refer to the same time period. In the BEEPS 2009 wave, information on the application for loans refers to the fiscal year 2007, while the usage information refers to past loans without time restrictions. Both pieces of information are necessary to construct a measure of access to credit and should cover the same time period. The World Bank Environment Survey (WBES), which covers more developing countries and is the equivalent survey to BEEPS, unfortunately also does not make it possible to study this question, since information on credit need and information on the usage of credit do not refer to the same period of time and therefore cannot be matched precisely.

from Uzbekistan, Tajikistan, Turkmenistan and Serbia as information on institutional characteristics is missing. We also leave out Turkey to focus on transition countries. So we ultimately analyze 5,762 firms in 23 countries, 14 countries from Central and Eastern Europe (Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Estonia, Macedonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia) and nine countries from the former Soviet Union (Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russia and Ukraine).

Stratified random sampling ensures that the samples are representative in each country. Firms from both manufacturing and service sectors were included, whereby the sectoral composition in the sample is determined by the relative contribution of manufacturing and service sectors to domestic GDP. Firms that operate in sectors subject to government price regulation and prudential supervision (e.g., banking, electric power, rail transport, water and waste) were not included in the sample (see EBRD, 2005a).

The questionnaire contains general firm characteristics and a detailed section on the financing of the firm. Information on the most recent loan is available and when loans are not used within a firm, additional information on the reasons are provided. In our sample, 47 percent of all firms currently have a loan. Among firms that do not use loans, about five percent were rejected while 93 percent did not apply for a loan. In two percent of all cases credit applications were still pending. It is unclear whether these firms will obtain access to loans, so we do not include them in our analysis. Additionally, firms cite multiple reasons why they did not apply for a loan. The answers can be broadly divided into two categories. First, some firms were discouraged from credit applications for reasons such as too high burdens in the application procedure, overly strict collateral requirements, excessively high interest rates or informal payments that have to be made to obtain a loan. Second, a firm may not have applied for a loan because it did not need one. In short, 36 percent of the non-applicants were discouraged from a credit application, while the major proportion of 64 percent had no need for bank financing. This differentiation is essential for identifying access to credit in the following analysis. Table 1.1 provides the descriptive statistics for these survey responses.

Table 1.1: Identifying access to loans

Does the firm have a loan?	Freq.	Percent
Yes	2,695	46.77
No	3,067	53.23
Total	5,762	100
If the firm does not have a loan, what was the reason?	Freq.	Percent
Firm did not apply for a loan	2,853	93.02
Application was turned down	141	4.60
Application for the loan is still pending	73	2.38
Total	3,067	100
If the firm did not apply, what were the main reasons? (multiple answers)	Freq.	Percent
Does not need a loan	1,830	46.27
Application procedure too burdensome	529	13.38
Collateral requirements too strict	564	14.26
Interest rates too high	786	19.87
Informal payments necessary to get bank loans	80	2.02
Did not think it would be approved	104	2.63
Others	62	1.57
Total	4,416	100
If the firm did not apply, what were the main reasons? (consolidated answers)	Freq.	Percent
No need (at least one answer is "does not need a loan")	1,830	64.14
Discouraged (none of the answers is "does not need a loan")	1,023	35.86
Total	2,853	100

1.2.2 Measuring Access to Credit

The detailed questionnaire on the financing of firms enables us to construct a direct measure of access to credit and to evaluate whether the usage of credit and perception-based indicators are suitable approximations for access to credit. For investigating access to credit it is essential to consider only firms that have demand for credit. To identify firms with credit demand, we make use of the above mentioned differentiation between rejected and discouraged firms and firms with no need for credit. We classify the following three groups as having demand for credit:

a. firms that are using loans,

b. firms that have applied for a loan, but were rejected and

c. firms that were discouraged from applying for credit.

A firm is classified as discouraged when it has not applied for a credit purely because it was discouraged from doing so, and not because it did not require credit. I.e., a firm is

Table 1.2: Coding of the dependent variables

Categories	Usage	Demand	Access	Freq.	Percent
Firm has a loan	1	1	1	2,695	47.37
No loan, because application turned down	0	1	0	141	2.48
No loan, because discouraged from applying	0	1	0	1,023	17.98
No loan, because no need	0	0	-	1,830	32.17

classified as discouraged if none of the multiple answers is "no need". Accordingly, the binary variable *demand* equals 1 for all three groups (a-c). It equals 0 if the firm does not have a loan because it had no need for credit and therefore did not apply for one. Subsequently, to analyze access to credit we consider only firms with credit demand.

Firms that demand credit and have a loan are classified as having access to credit (a), while firms with credit demand that do not have a loan are classified as being credit constrained (b, c). The latter group comprises discouraged firms and firms that applied for a loan, but were rejected. Hereby, we follow the literature on this topic and group firms that were rejected together with firms that were discouraged from applying (see, e.g., Popov and Udell (2012) for definitions for credit constraints of firms; Cox and Jappelli (1993) and Duca and Rosenthal (1993) for credit constraints of households). The variable *access* equals 1 if a firm has a loan and zero if a firm does not have a loan, although it does have credit demand.

As for the usage of credit, we construct the variable *usage*, which equals 1 if a firm has a loan and zero otherwise. This measure is equivalent to former studies that approximate access to credit by the usage of credit. Among firms without loans, the usage measure does not differentiate between credit constrained firms (including rejected and discouraged firms) and firms that actually have no demand for credit. Table 1.2 summarizes the distribution of firms among these groups and further clarifies the difference between the access and the usage measure.

For the perception-based indicator firms were asked to evaluate whether access to financing in general, i.e., the financing available from banks, was problematic in terms of the operation and growth of their business. The variable *perceived access* varies from 1 “major obstacle” to 4 “no obstacle”, such that a higher value signals a better access to finance. The distribution of *perceived access* among different groups is presented in

Table 1.3: Distribution of *perceived access* among financial categories

	Demand	No Demand	Mean Diff.
Perceived Access	2.516	3.135	-0.619***
	Access	No Access	Mean Diff.
Perceived Access	2.670	2.516	0.510***
	Usage	No Usage	Mean Diff.
Perceived Access	2.670	2.756	-0.086***

Notes: The table reports differences in means for *perceived access* for the different categories of demand, access and usage. The results of a two-sample t-test with equal variances are provided in the last column. ***, **, * denote that the difference in means is statistically significant from zero at a 0.01, 0.05, and 0.10 level.

Table 1.3. In our sample, the average perception is 2.715, whereby a higher value indicates better access to credit. It is noticeable that the perception of access is significantly better among firms without credit demand (3.135) than for firms with demand (2.516). This strengthens our assumption that firms without credit demand state that they experience no obstacle regarding access to credit. Furthermore, firms that do not use loans have a significantly better perception than firms that have access to loans (2.756 versus 2.670), which indicates that firms without a loan are not necessarily credit constrained.

1.2.3 Regression Strategy

To investigate the determinants of access to credit, we first estimate probit regressions that investigate whether a firm with credit demand is successful in getting access to credit. Therefore, we restrict the sample to firms that have credit demand (groups a-c) and estimate the following probit model

$$\begin{aligned} access_i = \phi(&\alpha_0 + \alpha_1 age\ 0\text{-}7_i + \alpha_2 age\ 14+_i + \alpha_3 foreign_i + \alpha_4 state\text{-}owned_i \\ &+ \alpha_5 privatized_i + \alpha_6 small_i + \alpha_7 transparency_i \\ &+ \alpha_8 profits_i + \alpha_9 capacity_i + \eta_s + \lambda_c) \end{aligned} \tag{1.1}$$

where ϕ denotes the standard normal cumulative distribution function. η_s and λ_c denote sector and country fixed effects. The included explanatory variables are explained in Section 1.2.4.

Second, since the selection into the demand group might not be random and unmeasured determinants could jointly influence a firm's demand for a loan and a firm's probability of getting access to credit. If this unobserved heterogeneity is correlated with the covariates in the access estimation, the estimations suffer from an omitted variable bias. Therefore, we additionally control for potential selection bias by estimating a bivariate selection model that takes into account interdependencies between the selection and the outcome stage. We use a probit model with sample selection based on Heckman (1979), which implies binary outcomes for both stages. Under the assumption of a bivariate normal and independent error distribution, maximum likelihood estimation provides consistent estimators.[4] We estimate

$$Prob(access = 1 \mid demand = 1, x) = \frac{1}{\Phi(x\gamma)} \int_{-x\gamma}^{\infty} \Phi \left[\frac{x_1\beta + \rho\omega}{(1-\rho^2)^{1/2}} \right] * \phi(\omega) d\omega \tag{1.2}$$

with

$$\begin{aligned} access &= 1[x_1\beta + \epsilon > 0] \\ &= 1[\beta_0 + \beta_1 age\ 0\text{-}7_i + \beta_2 age\ 14+_i + \beta_3 foreign_i + \beta_4 state\text{-}owned_i \\ &+ \beta_5 privatized_i + \beta_6 small_i + \beta_7 transparency_i + \beta_8 profits_i \\ &+ \beta_9 capacity_i + \eta_s + \lambda_c + \epsilon_i > 0] \end{aligned} \tag{1.3}$$

$$\begin{aligned} demand &= 1[x\gamma + \omega > 0] \\ &= 1[\gamma_0 + \gamma_1 age\ 0\text{-}7_i + \gamma_2 age\ 14+_i + \gamma_3 foreign_i + \gamma_4 state\text{-}owned_i \\ &+ \gamma_5 privatized_i + \gamma_6 small_i + \gamma_7 transparency_i + \gamma_8 profits_i \\ &+ \gamma_9 capacity_i + \gamma_9 perceived\ competition_i + \gamma_{10} investment_i \\ &+ \eta_s + \lambda_c + \omega_i > 0] \end{aligned} \tag{1.4}$$

[4] A detailed derivation of the likelihood function for the probit model with sample selection can be found in Wooldridge (2002).

where *access* is the outcome and *demand* the selection equation. ρ is the correlation between ϵ and ω.[5]

For a robust identification additional exclusion restrictions are necessary, i.e., variables that generate nontrivial variation in the selection variable, but do not directly affect the outcome variable (Cameron and Trivedi, 2010). In our regression, we include a firm's individual perception of competition as exclusion restriction. After controlling for general sector-specific fixed effects, this measure from a firm's individual perception has the advantage of capturing firm-specific competition. Thereby (unobserved) variation of firms within the same sector is considered.[6]

The competitive environment should influence a firm's credit demand. Faced with greater competition, firms may invest more often in order to improve their position relative to other competitors and therefore they may need external finance more often. Alternatively, a too intense competition could also reduce the attractiveness of new investments and result in a lower credit demand. In both cases, the individual competitive environment should be relevant for a firm's credit demand. Banks, however, base their decision to grant a loan mainly on hard information, and specifically on figures that are observable in the firm's balance sheet. For the assessment of the competitive environment, banks mainly use industry ratings that disregard region- and firm-specific circumstances.[7] Thus, after controlling for fixed differences on sector (and country) level, additional variation from the individual perception of competition should not have a direct impact on a bank's decision to grant a loan.

To measure the competitive environment, firms were asked what would happen if they raised the prices of their main product line or main line of services by ten percent in the domestic market. The variable *perceived competition* takes the value 1 if they expected

[5]If the assumption of bivariate normal error distribution is not fulfilled, the estimator would be biased. In the sensitivity analysis in 1.4.2 we therefore present a linear Heckman two-step estimation that relies on the weaker distributional assumption of univariate normality. Since the results are very similar, we conclude that the assumption of bivariate normal error distribution is unproblematic and decide to use the more efficient maximum likelihood estimator in the baseline regressions.

[6]E.g., Tang (2006) and Schmiele (2012) use similar individual perception-based measures to explain why firms exhibit different levels of innovation activities within the same product market.

[7]This assumption is confirmed in the guide of a development bank compiled for firms applying for loans at commercial banks. It gives firms advice on how to apply and provides explanations for bank behavior (LfA, 2009).

customers to continue to buy the same quantities, 2 if they were predicted to buy a slightly reduced quantity, 3 if they were expected to buy a much lower quantity, and lastly 4 if many buyers were forecasted to switch and buy from the competitor instead. Additionally, we include the dummy variable *investment* in the demand equation to directly measure a firm's previous investments. It equals 1 if the firm has acquired a new production technology within the last 36 months. Consequently, *perceived competition* and *investment* should provide good demand shifters (see Popov and Udell (2012) for a similar rationale). Since we cannot test the validity of the exclusion restriction, we assess the stability of the results and provide alternative instrumentation strategies in Section 1.4.1. The results do not change.

To evaluate whether the measures based on the usage of credit and on perception-based indicators identify the same determinants of credit constraints, we re-estimate equation (1) for the dependent variable *usage* (probit regression) and the perception-based indicator *perceived access* (OLS regression), respectively.[8]

1.2.4 Explanatory Variables

The following section describes the explanatory variables of all specifications.

Firm-Level Explanatory Variables Judging by the policy debate and the existing evidence, there are several important firm-specific characteristics that may influence access to credit (see, e.g., Beck et al., 2006; Brown et al., 2011). These include the size, age and ownership of the firm. With respect to size, different effects interfere. On the one hand, the banks' costs for conducting a credit evaluation do not vary a lot with the amount of the loan. Thus, smaller loans are less profitable for banks, which may therefore be reluctant to lend to smaller firms. On the other hand, there is a diversification effect by granting many small loans. The dummy variable *small* controls for the size of a firm, it equals 1 if the number of employees is less than 50.

[8]The *perceived access* variable exhibits four different categories, so that we also have estimated ordered probit regressions. The results are very similar. For reasons of interpretability, we report the OLS results.

For newly founded firms the information asymmetries faced by a creditor are most severe. Older firms already have a track record and can (ideally) show that they have always repaid on time. At the same time, the age of a firm should also influence credit demand. Depending on the stage of development of a firm, financial needs differ and so do the alternative sources of finance available. To measure the effect of age, we use dummy variables to take account of young firms (0 - 7 years), transition firms (8-13 years) and pre-transition firms (14 years or more) that were established before 1991.

In transition countries, the ownership structure has some special features. After the demise of the socialist system all firms were basically state-owned. Since then many of the firms have been privatized with the aim of rendering them more efficient. From this point of view, privatized firms should be better debtors. However, if state-owned firms have a soft budget constraint, they will not fail and therefore the bank does not face a risk financing them. The effect of ownership structure is captured with the dummy variables *private*, *privatized* and *state-owned*. Furthermore, we control for the nationality of a firm and include the dummy variable *foreign*, which equals 1 if the largest shareholder is a foreign company.

Firms can try to reduce the information asymmetries faced by the investors by becoming more transparent, for instance, through reporting their balance-sheets according to international accounting standards and having them audited by a renowned auditing company. The variable *transparency* takes the value 0 if a firm neither uses international accounting standards nor external audits; it takes the value 1 if at least one of them is used and the value 2 if both are used.[9]

Moreover, the chance of being granted a loan depends on the firm's default risk. We capture this risk by the profits of a firm. The dummy variable *profits* equals 1 if the firm realized positive profits in 2003 and zero otherwise. The utilization capacity should indicate the order situation and further approximate a firm's capability. The variable

[9]This measure is based on Brown et al. (2009b). The degree of transparency is determined by firms' choices within regulatory limits. However, in the following analysis it is treated as an exogenous variable, referring to robustness checks provided by Brown et al. (2009b). Using the same measure of transparency, they control for potential endogeneity using instrumental variables estimations and show that analysis of cost and usage of credit using BEEPS data do not change.

capacity measures the degree of output in comparison with the maximum possible output (in percentage).

The sector in which a firm operates plays an important role. Depending on the nature of the firm's business, the need for financing might differ substantially. For instance, the size of investments is much higher in manufacturing than in retail. Thus, the demand for credit might strongly depend on the firm's sector. However, we expect that access to loans depends on firm-specific, rather than on sector-specific factors. We control for differences in sector characteristics by using dummy variables that are equal to 1 if over 50 percent of a firm's sales comes from this sector.[10] The sectors are mining and quarrying (sector 1), construction (sector 2), manufacturing (sector 3), wholesale, retail and repairs (sector 4), real-estate, renting and business services (sector 5), hotels and restaurants (sector 6) and others (sector 7). Table 1.4 summarizes the descriptive statistics of the firm-level explanatory variables.

Country-Level Explanatory Variables To gain further insights into macroeconomic determinants, we additionally estimate all specifications with country-level explanatory variables that are expected to influence access to credit (instead of country dummies λ_c).

The legal framework is of particular importance, since it shapes the credit contracts that can potentially be designed through two channels. The first channel is the protection of creditor rights as codified in the law. The better creditor rights are protected, the more likely banks are willing to provide loans (La Porta et al., 1998). The second channel is how well the protection of creditor rights is indeed enforced (Pistor et al., 2000). We capture the first channel through an index of *creditor rights* constructed by the World Bank. It measures the degree to which collateral and bankruptcy laws protect the rights of borrowers and lenders and ranges between 1 and 10. A higher score facilitates lending and therefore leads to better access to credit. For the second channel, we use the effectiveness of legal institutions measured by the days it takes to enforce a contract (*enforcement*).

[10]The majority of the firms operate in a single sector. We additionally construct a sector measure that takes into account where the maximum proportion of sales comes from, which does not change the results.

Table 1.4: Firm-level explanatory variables

Country	N	Age (in years)	Age 0-7	Age 14 +	Foreign	State-Owned	Privatized	Small	Transparency	Profits	Capacity	Investment	Perceived Competition
Albania	145	10.54	0.38	0.08	0.04	0.07	0.06	0.77	0.94	0.92	76.19	0.42	2.48
Armenia	296	14.64	0.45	0.30	0.07	0.05	0.30	0.79	0.72	0.98	81.93	0.55	2.50
Azerbaijan	154	12.24	0.40	0.19	0.16	0.13	0.05	0.56	0.92	0.99	86.29	0.74	2.44
Belarus	257	12.88	0.35	0.21	0.10	0.12	0.03	0.72	0.47	0.87	80.84	0.28	2.48
Bosnia	123	20.17	0.31	0.33	0.14	0.11	0.15	0.54	0.70	0.80	82.24	0.48	2.58
Bulgaria	220	17.91	0.20	0.35	0.11	0.09	0.15	0.71	0.73	0.80	85.11	0.29	2.59
Croatia	124	24.30	0.09	0.50	0.11	0.10	0.23	0.61	1.15	0.95	85.47	0.47	2.52
Czech Republic	261	12.89	0.28	0.26	0.10	0.07	0.08	0.76	0.45	0.92	86.78	0.25	2.41
Estonia	116	14.68	0.17	0.30	0.16	0.10	0.12	0.66	1.67	0.90	81.88	0.20	2.56
Georgia	89	20.97	0.39	0.35	0.09	0.11	0.30	0.73	1.19	0.78	77.02	0.34	2.61
Hungary	436	16.08	0.23	0.39	0.12	0.05	0.11	0.70	0.89	0.85	80.66	0.16	2.90
Kazakhstan	448	10.26	0.50	0.15	0.06	0.05	0.20	0.72	0.44	0.88	85.97	0.34	2.38
Kyrgyzstan	143	20.41	0.24	0.41	0.15	0.11	0.37	0.62	0.90	0.79	76.75	0.49	2.62
Latvia	131	15.45	0.37	0.19	0.08	0.11	0.08	0.77	0.83	0.68	77.85	0.29	2.34
Lithuania	107	13.83	0.21	0.22	0.09	0.09	0.14	0.70	0.64	0.75	82.37	0.32	2.90
Macedonia	123	20.97	0.25	0.41	0.10	0.12	0.19	0.69	0.53	0.80	80.92	0.31	2.67
Moldova	235	11.74	0.32	0.16	0.09	0.06	0.22	0.66	0.22	0.63	78.48	0.40	2.46
Poland	738	17.83	0.21	0.48	0.06	0.06	0.07	0.73	0.46	0.87	83.86	0.37	2.85
Romania	393	16.39	0.20	0.30	0.08	0.06	0.12	0.65	0.60	0.83	86.66	0.41	2.34
Russia	407	12.86	0.43	0.20	0.10	0.10	0.10	0.63	0.50	0.88	84.01	0.35	2.33
Slovakia	133	13.87	0.23	0.30	0.13	0.07	0.08	0.71	0.67	0.86	87.95	0.23	2.66
Slovenia	152	24.39	0.09	0.61	0.07	0.11	0.24	0.68	0.64	0.76	87.01	0.34	2.36
Ukraine	458	15.08	0.38	0.24	0.10	0.07	0.15	0.70	0.50	0.83	76.46	0.33	2.32
Total	5689	15.48	0.30	0.30	0.09	0.08	0.14	0.70	0.63	0.85	82.61	0.35	2.54

Notes: The table presents the mean values for the firm-level explanatory variables across countries. Definitions and sources of all variables are summarized in Table A.1.

Credit markets are subject to substantial problems of asymmetric information, which are most severe in emerging markets. *Information sharing* devices such as credit registries are an important mechanism for reducing information asymmetries by providing information on, for instance, whether a firm has defaulted on a loan previously. Thus, their existence should make access easier, particularly for more opaque firms.[11] Here we use an index developed by Brown et al. (2009b). This index measures the presence and structure of public credit registries and private credit bureaus. The value ranges from 1 to 5, the more detailed the information provided is and the longer the registry has existed, the higher the scale.

The effect of *foreign bank* presence on access to credit is controversial. On the one hand, foreign banks bring expertise and capital into the host market, which can improve access to credit (particularly for larger firms, as Giannetti and Ongena (2009) show). On the other hand, it is argued that foreign banks might focus on particularly lucrative projects, which are easily identifiable because they are transparent. As a result, access to credit might become more difficult (Detragiache et al., 2006 and Gormley, 2010). However, foreign bank entry also affects the behavior of domestic banks; they may start lending to more opaque firms and thereby benefit all firms (Dell' Arricia and Marquez, 2004, Giannetti and Ongena, 2009). We capture the presence of foreign banks by the market share of foreign-owned banks.

Moreover, we use the income level measured by the log of the GDP per capita (*logGDPpc*) and *inflation* as explanatory variables and include a measure of *bank concentration*. Table 1.5 summarizes the country-level explanatory variables. For all country-level variables we use average values for the years 2001-2003, with the exception of creditor rights and enforcement (2005 values, earlier values are not available). The definitions and data sources of all explanatory variables can be found in Table A.1 in Appendix A.

[11] There is a rich body of theoretical literature on the effects of information sharing on the behavior of borrowers and ultimately on the credit market (for a summary, see Brown et al., 2009b). Information sharing does not have positive effects on access to credit in all models. The effects depend crucially on the incentive problem specified in the model.

Table 1.5: Country-level explanatory variables

Country	N	GDPpc	Inflation	Foreign Banks	Creditor Rights	Information Sharing	Enforcement	Bank Concentration
Albania	145	1326	3.38	44.60	9	0	390	0.76
Armenia	296	780	3.67	54.53	4	0.67	440	0.90
Azerbaijan	154	788	3.88	4.63	7	0	237	0.81
Belarus	257	1423	51.70	12.00	4	0	275	0.72
Bosnia	123	1600	2.78	73.90	4	4	595	0.51
Bulgaria	220	1787	4.37	76.87	6	2.67	564	0.59
Croatia	124	5281	3.91	90.17	5	0	561	0.60
Czech Republic	261	5830	2.88	87.07	6	2.67	611	0.63
Estonia	116	4897	3.96	97.53	4	4	425	0.98
Georgia	89	791	4.91	20.80	5	0	285	0.76
Hungary	436	4942	8.37	78.33	6	5	395	0.63
Kazakhstan	448	1534	9.23	5.50	5	4	390	0.66
Kyrgyzstan	143	296	4.44	48.17	4	1	260	0.85
Latvia	131	3867	2.96	53.67	8	1	369	0.55
Lithuania	107	3809	-0.32	89.97	4	5	275	0.81
Macedonia	123	1719	3.35	47.37	6	4	370	0.80
Moldova	235	406	12.26	35.60	6	0	352	0.78
Poland	738	4637	2.04	71.47	4	3	830	0.69
Romania	393	1883	28.28	53.03	5	3.33	512	0.66
Russia	407	1986	15.25	8.10	3	0	281	0.29
Slovakia	133	5787	4.73	86.23	9	3	565	0.83
Slovenia	152	10681	7.26	17.00	6	4	1290	0.71
Ukraine	458	756	7.76	12.17	8	0	343	0.54
Overall Mean	5689	2835	9.68	47.52	5.36	2.15	481.89	0.66

Notes: The table presents the mean values for the country-level explanatory variables across countries. For all country-level variables we use average values for the years 2001-2003, with the exception of creditor rights and enforcement (2005 values, earlier values are not available). Definitions and sources of all variables are summarized in Table A.1.

1.2.5 Descriptive Statistics

The access measure considers only firms with credit demand and indicates whether a firm that has demand is successful in obtaining credit. In estimating access to credit, self-selection into demand might be present. Comparing differences in average firm characteristics between firms with and without credit demand can provide a first hint as to selection. A two-sample t-test for continuous variables (and a proportion test for binary variables) shows that the differences in means are significantly different from zero for most firm characteristics (Table 1.6, Panel A). We find that both groups differ significantly in ownership, size and transparency. Firms with credit demand are less often foreign- and state-owned, but more often privately-owned or privatized. Among firms with credit demand, 68 percent are small compared to 73 percent in the no-demand group. The comparison in means provides initial evidence that the selection into the demand group might not be random.

In contrast to the access measure, the usage measure does not take into account differences in firm-specific credit demand. Therefore, among firms that do not use loans no differentiation is made between firms that have credit demand (and are considered to be credit constrained) and firms without credit demand (unconstrained). However, these types of firms may differ systematically and aggregating them into one group might not make it possible to draw conclusions regarding credit constraints. To evaluate the degree of heterogeneity, we compare both groups with regard to differences in average firm characteristics (Table 1.6, Panel B). For the subsample of firms that do not use loans, the majority has no demand for credit (64 percent), while 36 percent are credit constrained. Firms that experience credit constraints ($demand$=1) are significantly more often young firms and less often foreign or state-owned. Firms without demand are, on average, more transparent and more often profitable than credit constrained firms. In short, the heterogeneity among firms without loans is large and the considerable fraction of firms with no credit demand indicates that the usage approach might provide misleading conclusions on credit constraints.

Table 1.6: Heterogeneity of firms with and without demand for loans

Panel A: All firms			
	Demand	No Demand	Mean Diff.
Age (in years)	15.656	15.125	0.531
Age 0-7	0.302	0.301	0.001
Age 8-13	0.390	0.408	-0.018
Age 14+	0.308	0.291	0.017
Foreign	0.083	0.114	-0.032***
State-owned	0.063	0.107	-0.043***
Private	0.854	0.779	0.075***
Privatized	0.154	0.115	0.039***
Small	0.680	0.731	-0.051***
Transparancy	0.652	0.599	0.053***
Profits	0.846	0.859	-0.013
Capacity	81.325	85.308	-3.983***
Panel B: Subsample of firms that do not use loans			
	Demand (constrained)	No Demand (unconstrained)	Mean Diff.
Age (in years)	13.607	15.125	-1.517**
Age 0-7	0.372	0.301	0.071***
Age 8-13	0.365	0.408	-0.043**
Age 14+	0.263	0.291	-0.028*
Foreign	0.051	0.114	-0.064***
State-owned	0.076	0.107	-0.031***
Private	0.874	0.779	0.094***
Privatized	0.874	0.779	0.095***
Small	0.850	0.731	0.119***
Transparancy	0.420	0.599	-0.179***
Profits	0.790	0.859	-0.069***
Capacity	80.454	85.308	-4.855***

Notes: Panel A reports differences in means of firm characteristics for firms with and without demand for the whole sample, Panel B for the subsample of firms that do not use loans ($usage$=0). For continuous variables the results of a two-sample t-test with equal variances and for binary variables the results from a two-sample proportion test are provided in the last column. ***, **, * denote that the difference in means is statistically significant from zero at a 0.01, 0.05, and 0.10 level.

1.3 Results

The aim of our study is to investigate whether measures based on the usage of credit or on perception-based indicators, that both do not consider firm-specific differences in demand, are suitable proxies for access to credit when information on demand is not available. Therefore, we first estimate the determinants of access to credit in Section 1.3.1. Second, we estimate the determinants affecting the usage of credit (Section 1.3.2) and the perceived access (Section 1.3.3) and compare the findings with those in the access estimations. In all specifications, standard errors are clustered on country-level.[12]

1.3.1 Access to Credit

Table 1.7 summarizes the estimation results for access to credit. The first two columns present the marginal effects evaluated at mean from the basic probit estimations. The first specification controls for country fixed effects by including country dummies. The second specification replaces the country dummies with explanatory variables at the country level. We find that small firms and state-owned firms are less likely to get access to credit, while transparent and profitable firms are more likely to have access. Young firms (0-7 years) have a higher probability of facing restricted access in comparison to established firms (8-13 years), while firms that were founded before transition (14+ years) do not differ in their access to credit. With respect to sector dummies, after controlling for firm-level determinants, no sector-specific differences can be found. The results for the firm-specific effects are robust and do not change when country-specific variables are added. We find that stronger creditor rights are associated with a better access to credit.

Columns 3a to 4b present the probit estimations with sample selection. For both specifications the Wald test of independent equations rejects the null hypothesis of uncorrelated error terms at a one percent significance level, such that the selection into credit demand is not random. In the selection equation (Column 3a), we find that small firms have a 6 percentage points lower probability of demanding a loan. This suggests that small firms might use internal financing sources more often or invest less

[12]Different levels of clustering are presented in the sensitivity analysis in Section 1.4.3.

Table 1.7: Access to credit

	Probit		Probit with Selection			
	Access (1)	Access (2)	Demand (3a)	Access (3b)	Demand (4a)	Access (4b)
Age 0-7	-0.040**	-0.042**	0.031	-0.035***	0.028	-0.035***
	(0.016)	(0.017)	(0.020)	(0.012)	(0.018)	(0.012)
Age 14+	-0.029	-0.029	0.007	-0.022	0.018	-0.023
	(0.023)	(0.023)	(0.019)	(0.017)	(0.017)	(0.016)
Foreign	0.019	0.015	-0.125***	0.046*	-0.128***	0.041*
	(0.037)	(0.034)	(0.027)	(0.025)	(0.026)	(0.024)
State-owned	-0.150**	-0.154**	-0.163***	-0.051	-0.173***	-0.054
	(0.068)	(0.067)	(0.037)	(0.044)	(0.037)	(0.046)
Privatized	0.009	0.037	0.002	0.009	0.011	0.025
	(0.022)	(0.030)	(0.019)	(0.016)	(0.021)	(0.020)
Small	-0.216***	-0.210***	-0.063***	-0.136***	-0.056***	-0.132***
	(0.019)	(0.021)	(0.015)	(0.016)	(0.017)	(0.018)
Transparency	0.099***	0.105***	0.022**	0.066***	0.029**	0.066***
	(0.019)	(0.018)	(0.009)	(0.014)	(0.012)	(0.012)
Profits	0.154***	0.136***	-0.020	0.118***	-0.033	0.106***
	(0.028)	(0.027)	(0.019)	(0.023)	(0.020)	(0.022)
Capacity	0.000	0.000	-0.002***	0.001**	-0.002***	0.001**
	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
Sector 2	0.056	0.043	-0.155**	0.062	-0.142**	0.050
	(0.084)	(0.088)	(0.064)	(0.058)	(0.063)	(0.060)
Sector 3	0.066	0.041	-0.122**	0.064	-0.126**	0.047
	(0.087)	(0.094)	(0.059)	(0.062)	(0.057)	(0.065)
Sector 4	0.067	0.064	-0.190***	0.079	-0.177***	0.073
	(0.073)	(0.074)	(0.061)	(0.051)	(0.059)	(0.051)
Sector 5	0.004	0.016	-0.295***	0.063	-0.277***	0.068
	(0.086)	(0.085)	(0.073)	(0.055)	(0.071)	(0.052)
Sector 6	0.062	0.074	-0.315***	0.098**	-0.301***	0.102**
	(0.079)	(0.080)	(0.055)	(0.043)	(0.053)	(0.042)
Sector 7	0.011	0.008	-0.198***	0.044	-0.184***	0.039
	(0.083)	(0.085)	(0.069)	(0.057)	(0.067)	(0.057)
Log(GDPpc)		-0.025			-0.028	-0.011
		(0.038)			(0.027)	(0.022)
Inflation		0.001			0.003**	0.000
		(0.001)			(0.001)	(0.001)
Foreign Banks		0.001			0.000	0.001
		(0.001)			(0.001)	(0.001)
Creditor Rights		0.017*			0.004	0.011*
		(0.010)			(0.006)	(0.006)
Information Sharing		0.014			0.010	0.008
		(0.012)			(0.009)	(0.006)
Enforcement		0.092			0.018	0.060
		(0.081)			(0.054)	(0.044)
Bank Concentration		-0.158			-0.054	-0.104
		(0.161)			(0.115)	(0.091)
Investment			0.055***		0.047***	
			(0.014)		(0.017)	
Perceived Competition			0.021***		0.021***	
			(0.007)		(0.008)	
Country FE	Yes	No	Yes		No	
Constant	Yes	Yes	Yes		Yes	
R-squared	0.132	0.102				
Number of Observations	3859	3859	5689		5689	
ρ			-0.784***		-0.803***	

Notes: The table presents marginal effects evaluated at the mean from the basic regressions for access to loans. In the probit regressions with sample selection (columns 3-4) the dependent variable in the outcome regression is access to loans, while demand for loans is the dependent variable in the selection equation. Standard errors are clustered on country-level and are reported in parenthesis. Sector coding: 1 mining and quarrying, 2 construction, 3 manufacturing, 4 wholesale, retail and repairs, 5 real estate, renting and business services, 6 hotel and restaurants, 7 others. The left out category for age is *age 8-13* (firms founded during transition), for nationality privately-owned firms and mining and quarrying for sectors. ρ is the correlation between the error terms. ***, **, * denote that the marginal effect is significantly different from zero at a 0.01, 0.05 and 0.10 level.

than large firms. *Capacity*, which approximates how successfully a firm attracts external orders, is significantly negative, indicating that more successful firms less often rely on debt financing. Foreign-owned firms have a 13 percentage point lower probability of demanding a loan. An explanation could be that foreign-owned companies have access to the internal capital markets of global holding companies and therefore rely less intensely on the host country's credit markets. Since we simultaneously control for profitability, we should be able to separate this effect from the second possible channel, namely that foreign investors acquire the more profitable firms. Additionally, state-owned firms are significantly less likely to demand credit than privately-owned firms. Our instruments *investment* and *perceived competition* are found to be relevant for credit demand. Firms that have invested in a new production technology and those facing more competition are more likely to demand credit.

After controlling for firm-level explanatory variables, sector-specific differences in credit demand are still present. Compared to firms in the base sector mining and quarrying, firms in all other sectors are less likely to have demand for credit. When including explanatory variables at the country-level, the firm-level results remain mostly unchanged, although we find only *inflation* to have a significant effect. Firms that are located in countries with a higher inflation rate have, on average, a higher demand for credit financing.

In the outcome equations (Columns 3b and 4b) the results show some important differences when compared to the probit estimations. In contrast to the basic probit regressions, foreign-owned companies have significantly better access to credit after controlling for selection into credit demand. Due to their lower demand, the better access enjoyed by foreign-owned firms is not identified in the basic probit regressions since both effects run in different directions and might cancel out. The same pattern can be observed for *capacity*. After controlling for credit demand, firms with a higher capacity utilization have better access to credit (which is in line with the interpretation of capacity utilization as a proxy for a firm's capability). Regarding state-owned companies, the restricted access identified in the probit regressions becomes insignificant when controlling for the lower demand of state-owned companies. Similar to the basic probit regression, better creditor

rights are associated with significantly better access to credit when controlling for the selection into demand.

1.3.2 Usage of Credit

Columns 1 and 2 in Table 1.8 present the estimation results for the usage of loans. For a better comparability the results from the access estimations are replicated in Columns 3 and 4. The estimated marginal effects differ substantially from those estimated for the access to credit. In contrast to the findings obtained in the estimations for access to credit, in terms of age we find no credit constraints of young companies. Here, the higher demand and the poorer access to credit enjoyed by young companies are not disentangled and the resulting coefficient is not significant. Foreign-owned companies have a significantly lower usage of credit. Interpreting a lower usage of credit in terms of credit constraints would be misleading. In the access estimations, foreign-owned companies are found to have a lower demand for credit, but conditional on demand they have a better access to credit. This is also similar for state-owned firms, which have a significantly lower usage due to lower demand, although they have no worse access to credit compared to private firms.

Analogously misleading interpretations would also be drawn for sector-specific effects. In the usage estimations, we observe that some sectors have a significantly lower usage of credits. This, however, is not due to sector-specific credit constraints, but can be explained by differences in demand. This finding suggests that sector-specific programs to improve access, such as public guarantees for loans to particular industries, would not reach the really financially constrained firms and therefore may be inefficient.

In terms of size, transparency and profitability, we find significant marginal effects with the same sign as in the access approach. However, differences occur in the magnitude of the estimated marginal effects. For small firms both approaches identify a higher probability of being financially constrained. In the access equation the probability of being financially constrained rises by 13.6 percent if a firm is small, compared to 20.6 percent in the usage equation. The usage approach overestimates the restricted access of

Table 1.8: Usage of credit

	Usage of Loans		Access to Loans	
	(1)	(2)	(3)	(4)
Age 0-7	-0.013	-0.016	-0.035***	-0.035***
	(0.018)	(0.018)	(0.012)	(0.012)
Age 14+	-0.012	-0.007	-0.022	-0.023
	(0.021)	(0.020)	(0.017)	(0.016)
Foreign	-0.096***	-0.098***	0.046*	0.041*
	(0.028)	(0.027)	(0.025)	(0.024)
State-owned	-0.202***	-0.204***	-0.051	-0.054
	(0.045)	(0.045)	(0.044)	(0.046)
Privatized	0.003	0.031	0.009	0.025
	(0.022)	(0.030)	(0.016)	(0.020)
Small	-0.206***	-0.191***	-0.136***	-0.132***
	(0.021)	(0.025)	(0.016)	(0.018)
Transparency	0.082***	0.092***	0.066***	0.066***
	(0.013)	(0.016)	(0.014)	(0.012)
Profits	0.096***	0.075***	0.118***	0.106***
	(0.018)	(0.020)	(0.023)	(0.022)
Capacity	-0.001***	-0.001***	0.001**	0.001**
	(0.000)	(0.001)	(0.000)	(0.000)
Sector 2	-0.034	-0.035	0.062	0.050
	(0.077)	(0.077)	(0.058)	(0.060)
Sector 3	-0.016	-0.033	0.064	0.047
	(0.083)	(0.088)	(0.062)	(0.065)
Sector 4	-0.058	-0.052	0.079	0.073
	(0.072)	(0.073)	(0.051)	(0.051)
Sector 5	-0.170**	-0.157**	0.063	0.068
	(0.069)	(0.070)	(0.055)	(0.052)
Sector 6	-0.149**	-0.139*	0.098**	0.102**
	(0.073)	(0.072)	(0.043)	(0.042)
Sector 7	-0.098	-0.091	0.044	0.039
	(0.074)	(0.074)	(0.057)	(0.057)
Log(GDPpc)		-0.036		-0.011
		(0.041)		(0.022)
Inflation		0.003		0.000
		(0.002)		(0.001)
Foreign Banks		0.001		0.001
		(0.001)		(0.001)
Creditor Rights		0.015*		0.011*
		(0.009)		(0.006)
Information Sharing		0.017		0.008
		(0.014)		(0.006)
Enforcement		0.073		0.060
		(0.089)		(0.044)
Bank Concentration		-0.149		-0.104
		(0.171)		(0.091)
Country FE	Yes	No	Yes	No
Constant	Yes	Yes	Yes	Yes
R-squared	0.086	0.060		
Number of Observations	5689	5689	5689	5689
ρ			-0.784***	-0.803***

Notes: The table presents the marginal effects evaluated at the mean from the probit regressions of usage of loans (column 1-2). Columns 3-4 replicate the marginal effects from the outcome equations of the probit regressions with sample selection for access to loans from Table 1.7. Standard errors are clustered on country-level and are reported in parenthesis. Sector coding: 1 mining and quarrying, 2 construction, 3 manufacturing, 4 wholesale, retail and repairs, 5 real estate, renting and business services, 6 hotel and restaurants, 7 others. The left out category for age is *age 8-13* (firms founded during transition), for nationality privately-owned firms and mining and quarrying for sectors. ρ is the correlation between the error terms. ***, **, * denote that the marginal effect is significantly different from zero at a 0.01, 0.05 and 0.10 level.

small firms, since it does not take into account their lower credit demand. With respect to transparency and profits, where we have found less strong demand effects, the usage approach obtains very similar results.

For the country-level variables we find very similar results. Better creditor rights, which were found to have a positive effect on the access to credit, do also significantly increase the usage of credits.

A graphical comparison of access and usage illustrates how systematic the underlying differences between both approaches are. In the estimation results, the firm-level explanatory variables for foreign ownership and age were found to differ considerably between the usage and the access regressions. Both variables are additionally available as continuous variables and allow separately nonparametric locally weighted regressions for the dependent variables *demand*, *access* and *usage* (see Figure 1.1). We find a concave relationship between age and the usage of credits. In terms of access to credit a positive relationship with a strongly increasing access to credit for older firms is found, while the demand for credit decreases with firm age. The concave relationship of usage captures the decreasing credit demand of older firms and shows that access and demand effects are not disentangled in the usage approach. A similar pattern can be observed for foreign ownership. While the demand for credit decreases with the share of foreign investors, access to credit increases. The usage of credits reflects both - the access and the demand effect. It increases in foreign ownership until a share of 50 percent is reached and subsequently decreases.

To summarize, the usage measure is found to be an imprecise approximation for access to credit. Firm-specific differences in credit demand are not captured in the usage measure. As a result, the demand and access effect interfere and firm-specific determinants of credit constraints are not properly identified.

1.3.3 Perception-based Indicator

Table 1.9 presents the regression results for the perception-based indicator. The determinants of the *perceived access* largely coincide with the identified determinants

of access to credit (Section 1.3.1). For size, transparency and profits, we find highly significant effects similar to the access approach: larger, more transparent and profitable firms have better access to credit. The credit constraints of young companies are also identified, however the effect is not significant in all specifications. In contrast to the usage approach, the better access to credit of foreign owned firms and successful firms in terms of the capacity utilization is identified - without information on credit demand. Furthermore, we find that firms in countries with higher GDP per capita have a significantly better perception of access to credit, while higher inflation rates are associated with a worse perceived access to credit. Interestingly, while the enforcement of contracts has no significant effect on access to credit, it influences the perception of access and a weaker enforcement (more days to resolve a dispute) is associated with worse perceived access to credit.

We use the comprehensive information on credit demand to further analyze whether the identified determinants of the perceived access differ with a firm's credit demand.

Figure 1.1: Locally weighted regressions

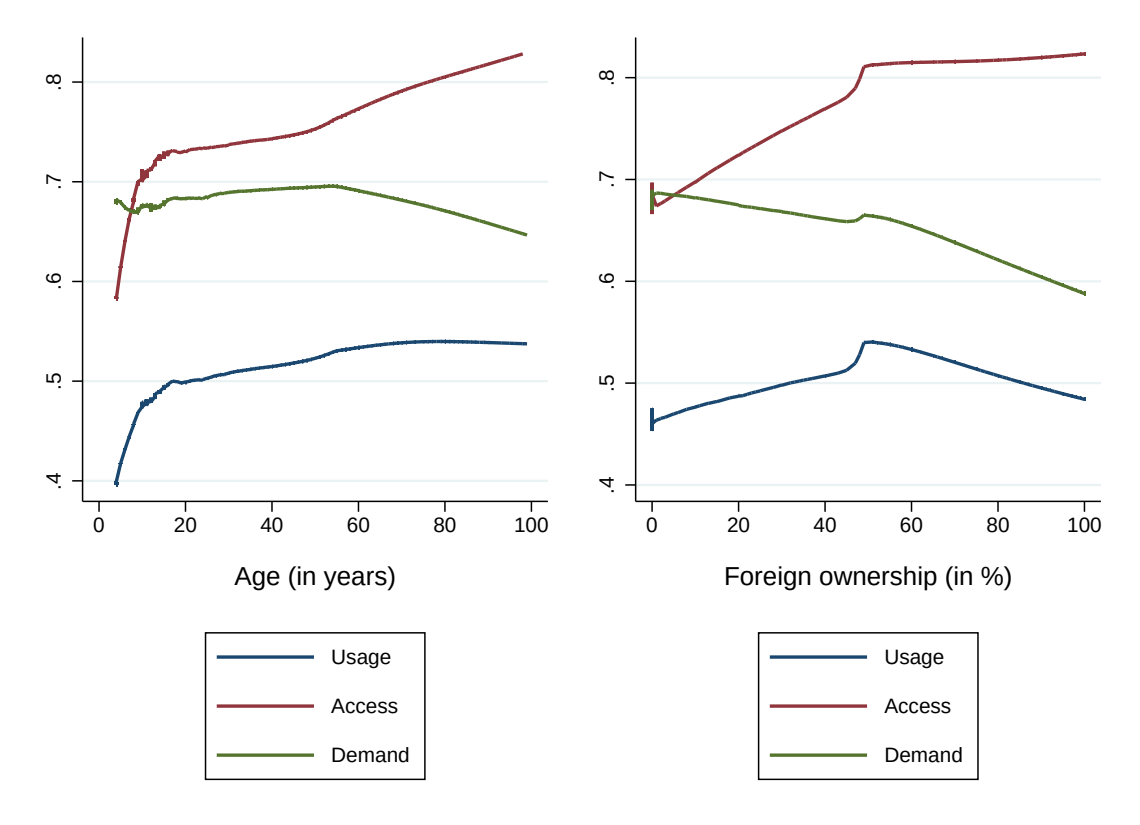


Table 1.9: Perceived access to finance

	All Firms		Firms with Demand		Firms without Demand	
	(1)	(2)	(3)	(4)	(5)	(6)
Age 0-7	-0.055	-0.107**	-0.053	-0.111**	-0.041	-0.061
	(0.040)	(0.040)	(0.046)	(0.044)	(0.046)	(0.047)
Age 14+	-0.061	-0.042	-0.123	-0.096*	0.051	0.097*
	(0.058)	(0.037)	(0.076)	(0.054)	(0.056)	(0.052)
Foreign	0.281***	0.277***	0.254***	0.261***	0.149	0.158
	(0.060)	(0.062)	(0.080)	(0.079)	(0.093)	(0.097)
State-owned	0.085	0.058	-0.055	-0.069	0.025	0.002
	(0.078)	(0.071)	(0.072)	(0.075)	(0.121)	(0.111)
Privatized	0.117*	0.096	0.138	0.115	0.057	0.057
	(0.068)	(0.066)	(0.082)	(0.088)	(0.076)	(0.068)
Small	-0.179***	-0.175***	-0.226***	-0.241***	-0.193**	-0.152**
	(0.040)	(0.047)	(0.054)	(0.061)	(0.069)	(0.071)
Transparency	0.066**	0.092***	0.095***	0.113***	0.049	0.092**
	(0.025)	(0.030)	(0.027)	(0.035)	(0.041)	(0.039)
Profits	0.164**	0.134*	0.195**	0.152*	0.078	0.048
	(0.066)	(0.067)	(0.074)	(0.079)	(0.089)	(0.090)
Capacity	0.005***	0.005***	0.005***	0.006***	-0.000	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)
Sector 2	-0.126	-0.148	-0.217	-0.247	-0.118	-0.159
	(0.263)	(0.250)	(0.305)	(0.285)	(0.234)	(0.244)
Sector 3	-0.121	-0.183	-0.132	-0.207	-0.259	-0.364
	(0.245)	(0.232)	(0.297)	(0.277)	(0.190)	(0.219)
Sector 4	-0.003	0.004	-0.054	-0.050	-0.184	-0.200
	(0.243)	(0.225)	(0.277)	(0.254)	(0.202)	(0.212)
Sector 5	0.129	0.153	0.013	0.067	-0.092	-0.132
	(0.235)	(0.214)	(0.280)	(0.257)	(0.215)	(0.221)
Sector 6	0.131	0.150	0.021	0.067	-0.153	-0.183
	(0.245)	(0.222)	(0.292)	(0.269)	(0.211)	(0.215)
Sector 7	-0.092	-0.071	-0.180	-0.163	-0.222	-0.231
	(0.249)	(0.228)	(0.283)	(0.258)	(0.234)	(0.241)
Log(GDPpc)		0.158*		0.152		0.128
		(0.080)		(0.091)		(0.090)
Inflation		-0.007**		-0.007*		-0.004
		(0.003)		(0.004)		(0.003)
Foreign Banks		-0.003		-0.003		-0.003
		(0.002)		(0.003)		(0.002)
Creditor Rights		0.023		0.027		0.022
		(0.030)		(0.036)		(0.026)
Information Sharing		0.012		0.009		0.036
		(0.034)		(0.040)		(0.028)
Enforcement		-0.431**		-0.426*		-0.419**
		(0.188)		(0.229)		(0.150)
Bank Concentration		0.133		0.380		-0.421
		(0.323)		(0.341)		(0.366)
Country FE	Yes	No	Yes	No	Yes	No
Constant	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.081	0.065	0.099	0.073	0.081	0.059
Number of Observations	5689	5689	3859	3859	1830	1830

Notes: The table presents coefficient estimates from the OLS regressions for the perception-based indicator *perceived access*. The dependent variable measures how problematic access to finance is for the operation and growth of a company and varies from 1 major obstacle to 4 no obstacle. Standard errors are clustered on country-level and are reported in parenthesis. Sector coding: 1 mining and quarrying, 2 construction, 3 manufacturing, 4 wholesale, retail and repairs, 5 real estate, renting and business services, 6 hotel and restaurants, 7 others. The left out category for age is *age 8-13* (firms founded during transition), for nationality privately-owned firms and mining and quarrying for sectors. ***, **, * denote that the coefficient is significantly different from zero at a 0.01, 0.05 and 0.10 level.

The regressions are estimated separately for the subsample of firms with credit demand (Columns 3-4) and firms without credit demand (Columns 5-6). Among firms with demand for credit, the results are highly similar to the results from the full sample of firms. Additionally, we find firms that were founded before the transition process to have a significantly worse perception compared to firms founded during transition, which was not present in the access approach. In the sample of firms without credit demand, we found hardly any significant determinants, which indicates that the results on the perceived access are mainly driven by firms with credit demand. However, the effects are strong enough to persist when all firms are pooled and differences in demand ignored, although the fraction of firms without demand is high.

To summarize, the perception-based measure of access identifies the same firm-level determinants as the direct measurement of access to credit, even if information on credit demand is not available. It therefore seems to constitute a much better approximation of access to credit than the usage of credit. However, the increase in R-square from 0.08 to 0.10 (despite the large drop in the number of observations) suggests that the explanatory power can be increased when additional information on credit demand is available.

1.4 Sensitivity Analysis

1.4.1 Alternative Exclusion Restrictions

For estimating access to credit, we use a probit model with sample selection following Heckman (1979), which takes into account interdependencies between the selection and the outcome stage. Identification rests on the exclusion restriction, which requires valid instruments for the selection equation. In the baseline regressions we have included a firm's individual perception of competition and previous investments as instruments. However, we cannot test whether the exclusion restriction is valid. To assess the stability of our results, we therefore first estimate the two-stage regression with *perceived competition* as the only instrument (leaving out the potentially endogenous *investment*). Second, we follow Popov and Udell (2012) and include *perceived competition* and *subsidy*

as exclusion restrictions.[13] Popov and Udell (2012) argue that on the one hand, having applied for state subsidy is likely to be a signal for external financial need and should constitute a good demand shifter and on the other hand, size, ownership and accounting standards are more readily observed by the bank than whether the firm receives subsidies. Further, they assume that firms in more competitive environments will have a higher demand for external finance, but that it is unlikely that product market competition will be correlated with the credit decision. Table A.2 presents the results with the alternative instruments. The results remain very stable. The correlation between the error terms of the selection and the outcome equation are highly significant (with the exception of the second specification, where the p-value of the Wald test equals 0.138). Size and significance of the marginal effects hardly change.

1.4.2 Assumption of Joint Normality

The maximum likelihood estimation of the binary response model with sample selection requires the assumption of a bivariate normal error distribution. This assumption might be too strong. As a robustness check, we estimate access to credit with a linear Heckman two-step procedure that includes the inverse Mills' ratio as an additional explanatory variable. The Heckman two-step estimator relies on a weaker distributional assumption of univariate normality and is expected to be more robust (Cameron and Trivedi, 2010). However, if bivariate normality is fulfilled, the maximum likelihood estimator is the more efficient estimator.[14] Table A.3 shows that the estimation results are very stable. The selection into demand remains significant and the signs and significant levels of most coefficients do not change either.

[13] In contrast to Popov and Udell (2012), we use the ordinal values of the variable *perceived competition* instead of a binary indication whether the competition is intense, to make full use of the available variation.

[14] A detailed theoretical discussion can be found in Cameron and Trivedi (2005).

1.4.3 Standard Errors Clustered on Industry-Country-Level

The standard errors in the baseline regressions are clustered at the country-level for 23 different country clusters. Although this might be a sufficiently large number of clusters, the underlying assumption for calculating cluster-robust standard errors requires the number of clusters to go to infinity. To assess whether this assumption is problematic in our regressions, we re-estimate the baseline regressions with standard errors corrected on industry-country level. Hereby the number of clusters increases to 154. Correlations in errors of firms within the same industry in one country are taken into account, while inter-industry correlations within one country cannot be captured with this clustering structure. Table A.4 summarizes the results. The standard errors of the firm-level coefficients are unaffected. The results for the country specific determinants are basically similar. In the probit model with selection, the presence of foreign banks and the enforcement of creditor rights have a significant positive coefficient (at the 10 percent level) and creditor rights keeps a significant positive coefficient. This indicates that our baseline standard error adjustment on country-level potentially overestimates the size of the standard errors.

1.5 Conclusions

In this paper we develop a direct measurement of access to credit, which takes into account whether a firm that has credit demand is successful in getting access to credit. With this we investigate how precise different approximating measurements are in predicting credit constraints. This evaluation is of particular importance as direct measurements for access to credit are not available when using balance sheet data and are often missing in survey data. As a consequence, access to credit often has to be approximated by measures based either on the usage of credit or on perception-based indicators, which both do not take into account a firm's demand for credit. Ignoring differences in firm-specific credit demand can hinder the identification of access to credit, as our main results show.

First, investigating access to credit we find that the selection into credit demand is not random and firms do self-select themselves. Not controlling for this selection can lead to biased estimations, particularly for determinants that affect demand and access in opposing directions. The effects may offset each other, such that coefficients are not significantly different from zero in estimating access to credit (e.g., coefficient for foreign ownership or capacity utilization) or have the wrong sign when the effect of demand dominates the access effect (e.g., coefficient for state-owned firms). As a consequence, firms with a lower demand can falsely be classified as credit constrained.

Second, the comparison of different measurements that approximate access to credit shows that the usage of credit does not allow drawing precise conclusions on credit constraints. We find considerable differences in the identified determinants of usage and access, which can be explained by differences in a firm's demand for credit. Interpreting the usage of credit in terms of access can both under- and overestimate restricted access, depending on the direction of the demand effect. The comparison between the direct access approach and the perception-based indicator, however, shows that these measures are able to identify firm-level determinants of restricted access, even when information on demand is not available. Thus, our analysis suggests that perception-based indicators provide a relatively good measurement for restricted access when information on credit demand is missing, and are better suited than measurements based on the usage of credit.

With regard to future survey design for investigating access to finance, our results stress the importance of including questions on the demand for external finance in questionnaires to be able to directly identify access to finance. Thereby it is of particular importance that information on demand and usage can be clearly matched, i.e., they should refer to the same time period (e.g., the previous fiscal year). Moreover, information on the application for finance is not sufficient to identify financial demand. Firms can be discouraged from applying for several reasons, which should be considered in the survey design. To capture potential selection bias, suitable exclusion restrictions for the selection into demand should be considered beforehand in the list of questions. Furthermore, our analysis shows perception-based indicators to be valuable approximations. To increase their precision, we recommend that firms should be likewise requested to

give information on their financial need in the questionnaire. With respect to future research, better information on firms' creditworthiness from matched balance-sheet data or additional questionnaire information on the necessary balance-sheet items would significantly improve research on access to finance.

Chapter 2

Patents in the Financing of R&D Intensive Start-up Firms: Evidence from Germany*

2.1 Introduction

Access to finance is a key determinant of innovation and economic growth. Information asymmetries and the absence of collateral can lead to market imperfections in financial markets so that even firms with profitable investment opportunities can be financially constrained, and hence restricted in their investment decisions (Stiglitz and Weiss, 1981). In particular, highly innovative start-up firms possess only short track records and often few tangible assets that can be used as collateral. Investment decisions of external resource holders are therefore made under considerable uncertainty about the survival probability of the venture. At the same time often substantial resources are required to fund early-stage projects, while revenues cannot be expected in the near future (Stuart et al., 1999). As a consequence, financial constraints are expected to be most severe for these entrepreneurs. Since start-ups in high-technology industries play an important role

*This chapter is based on joint work with Monika Schnitzer.

for innovation and structural change, these market frictions are expected to result in a decelerated rate of innovation and an overall slowdown in economic progress.

This paper investigates the question whether patents can mitigate financial constraints of R&D intensive start-up firms. Patents have the potential to reduce financial constraints through two different channels. First, the difficulties in getting access to external capital require innovative start-ups to develop signals for the largely unobservable value of the company and its commercial potential. Patents might function as signals for the innovative potential of a firm and its future success. Detailed and well-structured patent specifications enable a skilled recipient to evaluate the strengths and weaknesses of new inventions and technologies (Harhoff, 2011). The patent system can provide a mechanism for sorting the quality of innovative activity and reducing information asymmetries, which can decrease the risk for investors and facilitate the access to external finance for start-up firms.

Second, patents can serve as assets for financial investors. With the capability of providing licensing revenues and a salvage value in case of failure, patents exhibit the properties of collateral. Providing collateral is one important instrument to overcome information asymmetries in financial markets. Current legislative amendments facilitate collateralization with intangible assets. With the implementation of Basel II in 2007, intellectual property rights are accepted for capital adequacy in the European Union. In 2010 the German Accounting Law Modernization Act introduced the option to capitalize self-created intangible assets in German balance sheet regulations (Natusch, 2009).[1] In a study of U.S. originated secured syndicated loans, Loumioti (2011) shows that the collateralization of loans with intangible assets has increased in the recent decade and concludes that the collateralization of intangible assets is a sustainable credit market innovation that can reduce financial constraints.[2]

[1] Bittelmeyer et al. (2008) show in a survey of German companies that although the overall use of intellectual property rights as collateral is low among small and medium size businesses, the probability of securing a loan with intellectual property rights increases by 92 percent for R&D intensive firms.

[2] Loumioti (2011) finds that 21 percent of all loans include intangible assets as loan collateral. Although loans collateralized with intangibles have higher loan prices, they do not perform worse than other secured loans, so that collateralization of intangibles is not found to be associated with risky lending.

This paper empirically validates the theoretical predictions and investigates the role of patents in the financing of young ventures. Therefore, we develop a precise measure of access to finance, which takes account a firm's financial demand and considers whether a firm that demands a particular type of financing is successful in obtaining it. We separately investigate the impact of patents on the usage, demand, and access to external capital and thereby disentangle demand and supply side effects. To establish a causal effect of patenting, we use an instrumental-variable approach that takes into account potential endogeneity and reverse causality of patenting. We instrument a firm's patenting activity with the average patenting activity in the same 2-digit industry. Patenting varies across sectors due to differences in the effectiveness in patent protection (Cohen et al., 2000) and the complexity of technologies, which should be unrelated to a firm's individual access to finance. To capture variation in patent values, we use direct valuations by the patent owners to construct value-weighted patent counts.

For the analysis, we use detailed firm-level survey data on German start-up firms from high-tech and knowledge-intensive industries taken from the KfW/ZEW Start-up Panel. The survey has been conducted since 2008 and contains about 6000 German start-up firms per wave. Focusing on high-tech start-up firms and providing detailed information on financing and patenting, this dataset is ideally suited to investigate the role of patents in the financing of R&D intensive start-up firms.

The analysis on the effect of patents in the financing of start-ups reveals two important results. First, we find strong evidence for the endogeneity of patenting. We show that not taking into account issues of endogeneity and reverse causality can lead to highly biased estimates. Second, our results indicate that patents have a significantly positive effect on the usage of venture capital and bank financing, in particular when differences in patent values are considered. An increase in the usage of external finance may, however, not be fully attributable to an improved access to finance, since an increased financial demand of patenting firms could drive the results. The detailed financial information from the KfW/ZEW Start-up Panel allows to disentangle the demand and supply side effects and to separately estimate the impact of patents on demand and access to finance. Our findings show that patenting significantly increases the demand for venture capital

and bank finance. After controlling for financial demand, we find no significant effect of patents on the access to venture capital or bank finance.

The contribution of the paper is twofold. First, most of the previous studies on the role of patents in financing have not considered issues of endogeneity and reverse causality of patenting.[3] Thus it is not clear whether positive associations that were found in the literature can be interpreted as causal effects or mere correlations. We contribute to the literature by using an instrumental variable approach to establish a causal effect of patents and evaluate the extent of endogeneity.

Second, using the detailed financial information, we identify a firm's financial demand and investigate whether a firm that has demand for a specific type of finance is successful in obtaining it. Controlling for a firm's financial demand is essential, since firms that do not use external financing sources can either be restricted in their access to finance or might instead simply have no demand for this source of finance. Similarly, an increase in the usage of finance can be attributed to an improved access to finance or to an increase in financial demand. Previous studies have confirmed a positive effect of patents on the usage of venture capital finance. However, since demand and supply side effects are not disentangled in this financial measure, the alternative explanations for these findings, namely that a greater financial demand of patenting firms is driving the results, cannot be ruled out. To our knowledge, we are the first that separately investigate the impact of patents on the usage, demand and access to to external finance and thereby disentangle demand and supply side effects.

The paper proceeds as follows. Section 2.2 presents the relevant literature. The dataset and definitions of the key variables are described in Section 2.3. In Section 2.4 we present the empirical approach and discuss the identification strategy. The results are summarized in Section 2.5, Section 2.6 presents robustness checks. Section 2.7 concludes.

[3]One important exception is the study by Conti et al. (2013), which is discussed in Section 2.2.

2.2 Related Literature

The traditional function of the patent system is to foster innovations. Innovations exhibit the characteristics of public goods. Once the information of an invention is revealed, the knowledge is non-rival and non-excludable. The disclosure of inventions in patent specifications reveals information in such a way that following inventors can build on the newest stage of development. In exchange, the patentee gets the right to exclude others from the commercial use of the patented invention. Additional rewards originate from the possibility of licensing technologies and earning revenues from royalties. The prospective monopoly rents create incentives for the cost-intensive and uncertain R&D efforts and should increase the innovation activity in an economy.

Only in the recent literature has a signaling function of patents been considered (Long, 2002). According to Spence (1973) a signal should be costly to obtain, whereby the signaling costs have to be negatively correlated with productivity. The non-obviousness condition requires the technology to be sufficiently inventive, so that innovative and productive firms should exhibit lower patenting costs. Further, a patent application requires effort and time, strict guidelines have to be fulfilled, and the technological information must be edited in a structured manner (Harhoff, 2011).

The literature on entrepreneurship has identified three classes of information mechanisms for signaling the quality of new ventures. First, one strand of the literature emphasizes the importance of the educational background and reputation of an entrepreneur, including entrepreneurial experiences and former employment in high-status firms.[4] Second, it is argued that relationships with high-class affiliations can reduce the uncertainty for third parties.[5] Organizations of high reputation are perceived to have strong evaluative competences, so that affiliations with prominent partners can be trustworthy signals for the future success of a new venture (Stuart et al., 1999). The involvement of venture capitalists or prominent investment banks can certify the quality of a venture for initial public offerings and thereby lower the costs of going public (e.g., Megginson and Weiss, 1991; Gulati and Higgins, 2002). The third category of signaling mechanisms are previous

[4]See, e.g., Shane and Stuart (2002), Agarwal et al. (2004).
[5]See, e.g., Baum and Oliver (1991), Podolny (1994), Rao (2006).

activities of companies, whereby patenting falls in this category (Harhoff, 2011). The ability to patent new technologies signals a firm's technological ability and can be an indication of high-quality scientific and engineering employees (Stuart et al., 1999).

However, it is often difficult to establish causal effects of signaling. With regard to prominent affiliations, it is not possible to disentangle pure signaling effects from real benefits such as access to valuable information and resources. Affiliations such as venture capitalists or investment banks carefully select the most promising start-up firms, so that a positive association of high-class partners could be due to a careful selection of high quality firms.

The relevance of patents specifically to the process of obtaining external finance has been highlighted in the literature only recently. In general, a positive correlation is found between patents and venture capital financing (e.g., Baum and Silverman, 2004; Mann and Sager, 2007). Using matching procedures, Engel and Keilbach (2007) confirm that venture-capital funded German firms own more patents and can show that these patents are obtained before the investment decision of venture capitalists. They conclude that venture capitalists choose firms with demonstrated innovative output, such that owning patents increases the probability of obtaining venture capital finance.

Haeussler et al. (2009) investigate the signaling effect of patents on venture capital during the process of patenting. In a hazard rate analysis of venture-capital backed German and British biotechnology firms, they show that patent applications are associated with earlier use of venture capital, and highlight that venture capitalists pay attention to patent quality (approximated by forward citations).

Cockburn and MacGarvie (2009) find for U.S. software industries that firms having higher numbers of patents are more likely to receive funding from venture capitalists, even when patent thickets are present in the market. Further, they show that patent applications seem to matter more than patent grants. Despite the benefits from holding patents, Cockburn and MacGarvie (2009) emphasize that a large proportion of the sampled firms did not apply for patents and interpret this as an indication that the causality between funding and patenting may run in the opposite direction, so that firms that get access to external funding are more able to finance the substantial cost of patent prosecution. An

alternative explanation for these findings would be that patenting firms have developed new technologies and have a higher demand for external finance. This would also support the finding that patent applications appear to be more relevant than patent grants, since the financial demand should be highest when applying for patent protection for a newly developed technology.

Using a sample of U.S. semiconductor firms, Hsu and Ziedonis (2007) confirm a quality signal of patents on the estimate of start-up value by venture capital investors. They emphasize that signaling effects are larger in the early financing rounds, interpreting patents as a mechanism for overcoming the problem of the liability of newness. The stronger effect of patents in the early financing rounds could also be due to the fact that young ventures that, in particular, are at the beginning of their product cycle, have a higher financial demand and at the same time more intensively patent their newly developed technologies.

Conti et al. (2013) are the first to consider the potential endogeneity of patenting in start-up financing. They carry out a 2SLS estimation and instrument patenting with the number of founders with a Ph.D. in science or engineering. The acquired knowledge background should reduce the cost of making a patentable invention. However, the instrument is still endogeneous to the unobserved quality of the founders. They confirm a positive effect of patents on the usage of venture capital.

With regard to bank finance, there have been only a few studies so far. Audretsch et al. (2012) investigate the signaling effects of patents and prototypes on the usage of private equity as well as debt financing. Using a web-based survey for a sample of 900 persons that are planning to start a new venture, they divide the sample into ventures in the planning-stage and ventures in the early start-up stage. While no effect of patents and prototypes can be found in the planning stage, they confirm a positive correlation of patents and prototypes with the usage of venture capital in the start-up stage. With regard to debt financing, no effect has been found. Heger and Hussinger (2012) investigate the effects of pending patents on the market launch of new products and the usage of external financing for German high-tech start-ups. They find that both granted patents

and pending patent applications are associated with a higher probability of using venture capital, while no effects for the usage of debt financing could be found.

In comparison to these studies, our paper contains detailed considerations of a firm's financial demand. In previous studies, the supply side effect, i.e. an improvement in the access to finance of firms that have demand, was not disentangled from the demand side effects. Consequently, previous findings of a signaling effect of patents could be partly driven by an omitted financial demand of patenting firms. Furthermore, using an instrumental variable approach, our study captures potential problems of endogeneity and reverse causality, which has often been ignored in previous studies.

2.3 Data

For our analysis we use the KfW/ZEW Start-up Panel, which provides firm-level data on German start-up firms. Conducted since 2008, it covers on a yearly base about 6000 German start-up firms and contains detailed information on financing strategies and innovation activities, as well as detailed founder characteristics. The selection of firms is a random sample from the database of Creditreform, which is the largest credit rating agency in Germany. The survey considers firms that were founded within three years before the inquiry date. Stratification ensures that half of the surveyed firms operate in high-tech sectors. For the analysis, we consider firms from the high-tech sectors *superior technology manufacturing*, *high technology manufacturing*, *technology-intensive services* and *software*, as well as the technology-intensive sectors *non-high-tech manufacturing* and *skill-intensive services* and drop firms from non technology-intensive sectors.[6]

With regard to the financing strategy, information on the usage of different financial sources is available, including bank financing and venture capital financing. In addition, information on financial frictions with each particular financing source is available. This allows us to draw inferences about the financial demand separately for various financial

[6]Table B.1 in Appendix B summarizes the information on the aggregation of industries. Further information on the KfW/ZEW Start-up Panel can be found in Fryges et al. (2009).

sources and to construct a measure of access to finance, which takes into account whether a firm that has demand for a particular source of finance is successful in obtaining it.

For the analysis, we use the 2008 wave of the KfW/ZEW Start-up Panel, which combines comprehensive financial information with detailed information on a firm's patenting activity. Only in the 2008 wave, firms were questioned on their usage of intellectual property rights and on the importance of these rights for the company. Firms indicate whether patents are used or planned, and give information on the number of granted patents. Patenting firms give detailed information on the strategic functions of patenting and evaluate the importance of their patent rights for protecting their own competitive advantages.

Table 2.1 provides information on the patenting activities across the included sector groups. The variable DPAT indicates whether a firm has a positive amount of granted patents. Sectors with the highest proportion of patenting firms are *high technology manufacturing* (20.6 percent) and *superior technology manufacturing* (12.3 percent). PAT measures the total number of patent grants.[7] The highest average number of patents can be found in the sector *high technology manufacturing* (0.939), followed by *superior technology manufacturing* (0.526) and *technology intensive services* (0.293). VAL summarizes the evaluations of the importance of patents for protecting a firm's competitive advantages. The valuations vary between 1 "not important" and 5 "very important". Firms in the sector *superior technology manufacturing* exhibit the highest valuations for their patent rights (mean of 4.226), while also firms in the sectors *non-high-tech manufacturing* and *skill-intensive services*, in which by far fewer firms patent, have relatively high average valuations of patent rights (4.051 and 4.130).

2.3.1 Measuring Access to Finance

We are interested in the role of patents in the external financing of start-ups. The dependent variable should provide measures of the access to bank financing and venture capital financing. A precise measure of the access to finance ideally takes into account

[7] To control for outliers, we truncate the total number of patent grants at 22, which corresponds to the 99.74 percentile of the distribution.

Table 2.1: Patenting across sectors

Sector	DPAT	PAT	VAL
Superior technology manufacturing	0.123	0.526	4.226
High technology manufacturing	0.206	0.939	4.145
Technology-intensive services	0.049	0.293	3.917
Software supply and consultancy	0.047	0.065	4.000
Non-high-tech manufacturing	0.064	0.170	4.051
Skill-intensive services	0.033	0.111	4.130
All	0.067	0.274	4.062

a firm's financial demand and considers whether a firm that demands external finance is successful in obtaining it. However, due to data limitations, a precise measure is often not available and indirect approximations of the access to finance have been widely used. In the literature on the financial role of patents, a very common approximation is the usage of external finance. E.g., Conti et al. (2013) use the binary indication of the usage of venture capital, while Audretsch et al. (2012) use the binary indication of the usage of debt financing in their survey of the signaling role of patent protection.

If a firm receives venture capital financing, it clearly has access to venture capital. Yet, it is not clear whether a firm that does not use venture capital, is indeed financially constrained or whether it has no demand for it, e.g., because other sources of external finance are available. As a result, the comparison of firms that use a specific source of finance with firms that do not use this source may not reveal differences solely in the access to finance, but also differences in the demand for that financing source. Start-up firms, especially those which have patented new inventions, are probably in a growth stage, where it is necessary to invest in production facilities, distribution networks, or marketing, so that a simultaneous impact of patents on financial demand is very likely. Consequently, approximating access by the usage of finance cannot disentangle supply and demand side effects of financing.[8] To separate the supply and demand side effects, it is essential to identify a firm's financial demand.

The KfW/ZEW Start-up Panel allows us to construct a direct measure of the access to bank financing and to venture capital. We observe whether a firm uses a particular source

[8]See Hainz and Nabokin (2013) for a detailed discussion and evaluation of different approximate measures for the access to finance.

of external finance and have information whether that firm has experienced constraints in getting access for each particular source of finance. Combining this information enables us to approximate a firm's financial demand and construct a direct measure of its access to finance.

The variables *Usage-Bank* and *Usage-VC* are binary variables indicating whether a firm uses bank financing and venture capital financing, respectively. An increase in this measure could indicate a better access to finance, however, it cannot be ruled out that an increase is driven by an increase in demand. The binary variables *FC-VC* and *FC-BANK* indicate whether a firm has experienced financial constraints regarding venture capital or bank financing. This measure includes observations of all firms, i.e., firms with and without financial demand.[9] To construct a variable for financial demand, we combine the information on usage and financial friction in the following way. We categorize a firm that uses a particular source of finance as one having demand for that source. Further, a firm is assumed to have demand for a source of finance if it does not use it but has experienced financial frictions with that source. Finally, we categorize a firm that does not use a source of finance and also has not experienced financial friction with this source as having no demand for this source of finance. The binary variable *Demand-Bank* (*Demand-VC*) equals one if a firm demands bank financing (venture capital financing).

To evaluate the access to finance, only firms with demand are relevant. The binary variable *Access-Bank* equals one if a firm has demand and has not experienced financial frictions with bank financing (*Demand-Bank*=1 and *FC-Bank*=0), it equals zero if a firm has demand but has experienced financial frictions with bank financing (*Demand-Bank*=1 and *FC-Bank*=1). Table 2.2 summarizes the coding of the dependent variables *Usage*, *Demand* and *Access* and further clarifies the difference between a measure of usage of finance (that does not take into account whether a firm has financial demand) and a measure of access to finance (that does consider only firms with financial demand).

Table 2.3 presents descriptive statistics for the dependent variables. Regarding bank finance, 17 percent of all companies demand bank finance, while only 55 percent of them

[9]Note that it is not clear whether a firm that indicates not having experienced financial frictions, had indeed access to that source of finance or whether it had simply no demand for it. For this reason we do not directly use this measure as dependent variable.

Table 2.2: Coding of the dependent variables

Definition	Usage	Demand	Access
No usage and not financially constrained	0	0	-
No usage and financially constrained	0	1	0
Usage and financially constrained	1	1	0
Usage and not financially constrained	1	1	1

get access to loans. The overall usage of bank loans is therefore relatively low (11 percent). Venture capital financing is suitable for a small fraction of firms. In the sample, three percent of all firms use this source of finance. The share of firms demanding venture capital financing amounts to four percent, so that the resulting access rate is quite high (69 percent). This shows that the German venture capital market may be underdeveloped and suggests that mostly suitable firms apply for venture capital financing, such that a self-selection of firms seems to take place before the application process.

Panel A of Table 2.4 compares patenting and non-patenting firms in terms of the financial variables. We find that patenting firms have on average a higher usage of venture capital than non-patenting firms. At the same time, patenting firms have a higher probability of being financially constrained with regard to venture capital, which can be explained by a significantly higher demand for venture capital financing. For bank financing, we find that patenting firms have a higher probability of being financially constrained and simultaneously a higher demand for bank financing. These findings emphasize how important it is to control for a firm's financial demand to clearly separate demand and supply side effects.

2.3.2 Measuring Patenting Activities

To analyze the effect of patents on the access to finance, we use two different measures of a firm's patenting activity. First, we use the unweighted sum of patent grants (PAT). However, since the patent count itself is not a precise measure of inventive output (Harhoff et al., 2003), we also take into account the value of patent rights and construct an index of value-weighted patent counts.

Table 2.3: Descriptive statistics

	N	Mean	SD	Min	Max
Financial Variables					
Usage-VC	2830	0.029	0.168	0	1
FC-VC	2847	0.012	0.107	0	1
Demand-VC	2824	0.038	0.190	0	1
Access-VC	106	0.689	0.465	0	1
Usage-Bank	2829	0.111	0.314	0	1
FC-Bank	2847	0.079	0.270	0	1
Demand-Bank	2823	0.174	0.379	0	1
Access-Bank	492	0.547	0.498	0	1
Patent Variables					
DPAT	2780	0.067	0.250	0	1
PAT	2780	0.274	1.879	0	22
VAL	325	4.062	1.187	1	5
PAT*VAL	2780	1.184	8.675	0	110
Patent Functions					
Finance	334	2.997	1.537	1	5
Imitation	336	4.006	1.320	1	5
Licensing	337	2.893	1.534	1	5
Negotiation	335	3.015	1.432	1	5
Infringement	332	3.247	1.493	1	5
Reputation	334	3.506	1.308	1	5
Controls					
SIZE	2860	1.634	6.530	0	250
EXPR	2860	14.971	9.222	1	55
EDUC	2860	0.501	0.500	0	1
CORP	2860	0.026	0.158	0	1
INNO	2860	1.541	0.980	1	4
CAPA	2860	79.289	23.769	0	100

Table 2.4: Patenting firms versus non-patenting firms

	Patenting Firms	Non-Patenting Firms	Mean Diff.
Panel A: Financial Variables			
FC-VC	0.032	0.010	0.022***
Usage-VC	0.098	0.024	0.074***
Demand-VC	0.125	0.032	0.093***
Access-VC	0.783	0.771	0.012
FC-Bank	0.141	0.074	0.067***
Usage-Bank	0.120	0.109	0.010
Demand-Bank	0.239	0.169	0.070**
Access-Bank	0.409	0.563	-0.154*
Panel B: Control Variables			
SIZE	3.774	1.480	2.294***
EXPR	16.511	14.857	1.654**
EDUC	0.715	0.485	0.230***
CORP	0.032	0.025	0.007
INNO	2.554	1.470	1.084***
CAPA	79.522	79.251	0.271

Notes: The table provides mean comparison tests for various firm characteristics between patenting and non-patenting firms. ***, **, * denote that the difference in means is statistically significant from zero at a 0.01, 0.05, and 0.10 level.

The value distribution of patents is known to be notably right-skewed. Different methods have been developed in the literature to approximate the value of patents. Information from the patent specification provides proxies for the patent value. The number of (backward) citations indicates on how many earlier inventions, that verifiably fulfill the requirements of novelty and non-obviousness, a patent was built (Hall et al., 2005). Also the size of the patent family, i.e., the number of countries in which protection of the inventions was applied for, can indicate highly valuable patents. Further, the number of patent renewals can reveal a firm's private patent value (Lanjouw et al., 2003). Sherry and Teece (2004) approximate the value of patents by the number of appeals against a patent application. Only competitors that believe the patent imposes limits on their own business would bear the costs of such opposition, so that these patents are expected to be high value patents.

Harhoff et al. (2003) validate these indirect measures by using survey data of German patent holders with direct information on the value of their patent rights. They confirm that the number of references to the patent literature and the number of citations that a patent receives in the future is significantly positively related to the private patent value. Further, oppositions and a large international patent family are found to be relevant signals of valuable patents.

For our survey of start-up firms that were all founded between the years 2005 and 2008, indirect quality measures like forward citations or the number of patent renewals are not applicable due to the short future time horizon. To approximate the value of the granted patents , we instead use, similar to Harhoff et al. (2003), a direct valuation by the patent holder. Harhoff et al. (2003) use survey information on a hypothetical price for which the original inventor would be willing to sell the patent right. We instead use the individual evaluation of how important the patents of a firm are for protecting its own competitive advantages. With this information, we construct the value-weighted index of patent counts PAT*VAL, which is an interaction between a firm's number of granted patents (PAT) and its valuation of its own patent rights.[10] A caveat of our valuation measure may be that it is not patent specific, so that the valuation cannot be attributed

[10]Non-patenting firms have a PAT*VAL value of zero.

to specific patents. In our sample of start-up firms, it makes little difference whether the valuation is patent specific or refers to all patents, since most firms have only few granted patents. Table 2.3 summarizes the descriptive statistics for the patenting variables.

2.4 Empirical Approach

To analyze the role of patents in the access to external finance, we estimate varieties of the following baseline regression. FINANCE represents the different dependent variables usage, demand and access for the financial sources venture capital and bank finance. PATENTS stands for different measures of a firm's patenting activity.

$$FINANCE_i = \beta_0 + \beta_1 PATENTS_i + \beta_2 SIZE_i + \beta_3 CORP_i + \beta_4 R\&D_i + \beta_5 CAPA_i + \beta_6 INNO_i + \beta_7 EDUC_i + \beta_8 EXPR_i + \epsilon_i \quad (2.1)$$

To establish a causal effect of patents on the access to finance, it is essential to take into account potential issues of endogeneity and reverse causality of patenting activities.

Patenting is very likely to be correlated with unobserved firm characteristics related to a firm's capability, innovativeness and riskiness. Highly capable firms innovate more successfully and therefore should have a higher number of granted patents. In an ideal experimental setting, patenting would be allowed to a random subset of equally capable firms. By this means, comparing patenting and non-patenting firms in their access to finance would indicate a signaling effect of patents. However, with regard to patenting, a random setting is hardly possible. In a non-experimental setting though, ignoring an omitted variable bias due to unobserved firm capability could over- or underestimate the effect of patents on the access to finance.

Further, patent applications involve filing fees, maintenance fees, and costs for legal advice. It is very likely that a better access to external finance therefore influences a firm's decision to patent, causing a problem of reverse causality.[11]

To guard against omitted variable bias and reverse causality, we apply an instrumental variable approach and instrument the number of a firm's patents by the average number of patents of firms within the same industry.[12] This instrumental strategy is based on the following reasoning. Patenting activities differ significantly among sectors. One reason for this variation is that products consist of differently complex technologies. The respective technologies thereby differ in the number of separate inventions that they build on, and in the number of separate patent applications.

Another important reason for patenting activities on varying intensity is that the effectiveness of patents, i.e., the evaluation of patents in terms of protecting intellectual property, is perceived very differently among sectors. In a survey of U.S. manufacturing firms, Cohen et al. (2000) show that the perceived effectiveness of patent protection varies substantially across industries, being most important in medical equipment and drugs, followed by special purpose machinery, computers, and auto parts. They also find that firms value other protection strategies, such as secrecy and lead time, equally important or even more important than patent protection. These results demonstrate that there are important sector-specific differences in the strategies for protecting intellectual property rights, which results in different evaluations of patents and different patenting strategies across industries.

Consequently, the evaluation of patents and the number of patents of firms within the same industry should be a strong predictor for a firm's patenting activity and patent evaluation. We define firms that are active in the same two-digit NACE industry as relevant firms and instrument a firm's patents by the sector-specific average number of

[11] In the 2008 Berkeley Patent Survey, firms report that the costs for their recent patent have been $38,000 (Graham et al., 2009). Thereby, also opportunity costs associated with time invested in the preparation of patent applications by managers and engineers can be significant (Graham and Sichelman, 2008).

[12] A similar strategy has been used in a different setting by Desai et al. (2006) and Gumpert et al. (2011).

patents.[13] At the same time, the sector specific patent evaluation and the patenting activity should have no direct effect on a firm's individual access to finance and should create an exogenous variation in a firm's patenting activity. Further, the average number of patents within the same industry should be exogenous to a particular firm's unobserved characteristics.

Further, one might be concerned that the described problem of reverse causality might also be relevant for a firm's R&D activity. Firms that obtain access to external finance might invest the additionally available capital in further R&D. Since R&D is expected to be an essential determinant for the access to venture capital, we include a firm's R&D activity as explanatory variable. However, to avoid potential problems of reverse causality with regard to R&D, we apply a similar strategy than for patenting activities (measures by the number of employees that deal with research and development activities), and instrument a firm's R&D activity with the average R&D activity of firms within the same sector.

We additionally control for a variety of firm- and founder-specific characteristics. With regard to general firm characteristics, we control for firm size. SIZE measures the number of full-time employees. The dummy variable CORP indicates whether the firm is part of a larger corporation. To further approximate a firm's capability and success, we control for the degree of capacity utilization, CAPA. As argued above, the patent activity of a firm is expected to be highly correlated with a firm's innovativeness. Although we try to disentangle patenting from innovativeness with an instrumental variable approach, we include a measure of innovativeness to strengthen the results: INNO indicates whether a firm has introduced a market innovation at regional, national or international level since foundation.

To approximate the human capital of the founder, we include measures of education and experience. The dummy variable EDUC equals one if a founder has a university education (i.e., applied university degree, university degree, or PhD). The variable EXPR specifies how many years of industry experience the founder already has in the relevant industry.[14]

[13] We disregard sector classes with less than 5 firms and finally get 31 different sector classes. Note that this instrumenting strategy does not allow including sector dummies.

[14] Table B.2 in Appendix B gives detailed definitions of all variables.

Panel B of Table 2.4 compares patenting and non-patenting firms in terms of the explanatory variables. We find that patenting firms are on average larger in size, have more experienced founders with a higher level of education, and are more innovative than non-patenting firms.

2.5 Results

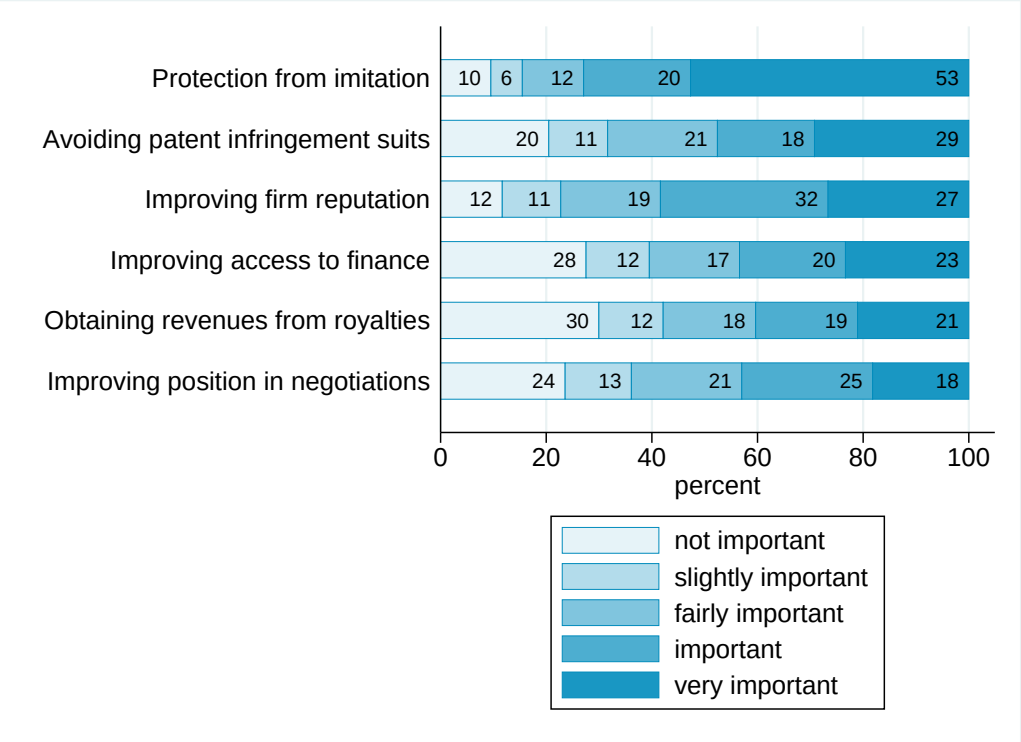
Before we turn to the question of whether patents can mitigate financial constraints of R&D intensive firms, we present a descriptive analysis on the various functions of patents. The detailed evaluations and perceptions of the surveyed firms allow us to assess the relevance of a financial function of patents and to identify the types of firms that rely on the financial function of patents. This is followed by the analysis on the effect of patenting on the access to external finance. We explore two financial sources: bank financing and venture capital financing.

2.5.1 Patent Functions

The traditional role of patents is to protect firms from imitation, to avoid litigation, or to obtain returns from licensing. Besides these traditional functions, patents can also have a financial function, by facilitating the access to finance through signaling the capability of the firm or through providing collateral. To gain a better insight into the role of patents in the financing of start-ups, we start with a descriptive analysis of whether start-ups rely on a financial function of patents. The 2008 wave of the KfW/ZEW Start-up survey contains a detailed questionnaire about the potential functions of patents. Firms that are using patents or planning to patent are asked to evaluate how important particular functions of patents are for their own company. The assessment ranges from 1 "not important" to 5 "very important". Table 2.3 summarizes the mean evaluations among firms. Figure 2.1 presents the detailed distributions of the single answers.

Among all patent functions, "protection against imitation" plays a major role (mean evaluation of 4.0). Of all patenting start-up companies, 73 percent assess patents as

Figure 2.1: Importance of patents



important or very important for protection against imitation (see Figure 2.1). The second most important function is "improving reputation" (3.5), which could be interpreted as a general signaling function to third parties. The functions "avoiding patent infringements" (3.2), "improving position in negotiation" (3.0), "obtaining revenues from licensing" (2.9) and "improving access to finance" (3.0) exhibit very similar mean evaluations. However, it is important to note that 43 percent of all start-up firms value patents as important or very important in improving access to finance, so that the financial function of patents seems to play a significant role for certain firms. The high standard deviation of the financial patent function also indicates that its valuation is very heterogeneous among firms.

To identify which type of firm relies on a financial function of patents, we estimate ordinary least-squares regressions of the financial evaluation on firm characteristics, and compare the results with estimates for the traditional function "protection against imitation" (Table 2.5).[15] In addition to the above introduced control variables, we include

[15]In the sensitivity analysis, bivariate ordered probit regressions are presented, which additionally capture interdependencies between the evaluations of a particular firm, but require stronger distributional assumptions. The results are very similar.

variables that capture the financial situation of a firm. The binary variable *Demand-Bank* indicates whether a firm has demand for bank financing, *Usage-Bank* captures whether a firm uses bank financing, and *FC-Bank* indicates whether a firm has experienced financial frictions in obtaining bank financing (there are analogues for venture capital financing).[16]

Table 2.5: Financial functions of patents

	Protection from Imitation			Improving Access to Finance		
	(1)	(2)	(3)	(4)	(5)	(6)
SIZE	0.004***	0.004***	0.004**	0.004	0.004	0.004
	(0.002)	(0.002)	(0.002)	(0.005)	(0.005)	(0.005)
EXPR	-0.003	-0.003	-0.002	0.000	0.000	0.002
	(0.007)	(0.007)	(0.007)	(0.008)	(0.008)	(0.008)
EDUC	-0.321**	-0.319**	-0.281*	-0.014	0.002	0.023
	(0.150)	(0.150)	(0.151)	(0.187)	(0.186)	(0.187)
CORP	0.783***	0.773***	0.783***	-0.626	-0.672	-0.529
	(0.170)	(0.173)	(0.170)	(0.505)	(0.509)	(0.502)
INNO	0.047	0.047	0.056	0.142**	0.143**	0.156**
	(0.059)	(0.059)	(0.058)	(0.070)	(0.070)	(0.071)
CAPA	-0.002	-0.002	-0.002	-0.010***	-0.011***	-0.011***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
R&D	0.020	0.020	0.023	-0.001	0.001	0.025
	(0.032)	(0.033)	(0.030)	(0.040)	(0.041)	(0.039)
Demand-Bank	-0.026			-0.098		
	(0.170)			(0.201)		
Demand-VC	0.085			0.765***		
	(0.205)			(0.238)		
Usage-Bank		0.011			-0.025	
		(0.201)			(0.237)	
Usage-VC		0.108			0.841***	
		(0.229)			(0.262)	
FC-Bank			0.009			-0.055
			(0.213)			(0.257)
FC-VC			0.097			0.842**
			(0.317)			(0.369)
Constant	4.459***	4.455***	4.396***	3.569***	3.584***	3.586***
	(0.426)	(0.428)	(0.409)	(0.493)	(0.497)	(0.475)
N	330	330	333	328	328	331
R-squared	0.046	0.046	0.046	0.043	0.041	0.034

Notes: The table presents the coefficients from OLS regressions of the importance of the patent functions "protection from imitation" and "improving access to finance". All standard errors are adjusted for heteroscedasticity. ***, **, * denote that the coefficient is significantly different from zero at a 0.01 0.05 and 0.10 level.

[16] We do not include *Access-Bank* and *Access-VC* as control variables, since the number of observations for these regressions would be too low.

We find that larger firms and firms that are part of a larger company have a significantly higher appreciation for the traditional function "protection against imitation", while these determinants do not play a role for the evaluation of the financial function. Firms that are characterized as innovative (in terms of having introduced market innovations since foundation) have a significantly higher valuation for the financial function of patents, while they do not differ in their assessment of the traditional "protection against imitation" function. Further, more established firms (measured by the capacity utilization) have a lower appreciation for the financial patent function, although no differences for the imitation function exist.

With regard to the financial control variables, we find interesting differences between both patent functions. All financial variables are insignificant in the regressions of the traditional patent function, indicating that the financial situation does not change the evaluation for protection from imitation. For the patent function "improving access to finance", we find a significantly higher evaluation by firms that demand venture capital, firms that use venture capital, and firms that have experienced financial friction with venture capital, while no effect for any variable of bank financing is found.

The results show that improving access to finance is an important patent function among R&D intensive start-ups. In particular, innovative firms and less established firms that exhibit a higher riskiness, as well as firms that demand venture capital financing rely on a financial function of patents.

2.5.2 Patents in External Financing

To investigate whether patents improve the access to external finance, we estimate 2SLS regressions of Equation 2.1. Table 2.6 summarizes the results for bank financing, Table 2.7 for venture capital financing. As dependent variables we use different financial measurements. *Usage* (Columns 1-4) indicates whether a firm uses bank finance (venture capital finance) and captures supply and demand side effects. The estimations for *Demand* (Columns 5-8) and *Access* (Columns 9-12) disentangle these effects. In each specification, we use two different measures for the patenting activity of a firm. The

variable PAT measures a firm's unweighted sum of patents, the variable PAT*VAL constitutes a value-weighted sum of patents. PAT is instrumented by the industry-specific average unweighted sum of patents, PAT*VAL is instrumented by the unweighted and value-weighted sum of patents. Further, R&D is instrumented by the sector-specific R&D average. To evaluate the severity of the endogeneity problem, we also present OLS regressions that do not take into account the potential endogeneity of patenting and R&D. In all specifications, we use robust standard errors.

2.5.2.1 Bank Financing

The estimated coefficients distinctly differ between the 2SLS and the OLS estimations. The robust Durbin-Wu-Hausman test strongly rejects the null hypothesis that PAT (PAT*VAL) and R&D are exogenous, indicating the presence of endogeneity and consequently inconsistent OLS estimations. The F-test for joint significance of the instruments in the first stage regression is rejected at high significance levels in all specifications (with the exception of the patenting variables in the access regressions). The values of the F-statistic vary between 8.02 and 11.41 in the usage and demand regressions. In the access regression only firms with demand for bank finance are considered, so that the number of observations is considerably smaller. This could explain the low F-statistics for the patenting variables. In the following we will focus on the 2SLS results.

For the usage of bank finance, we find significant positive effects for both measures of patenting. An increase by one standard deviation in the unweighted sum of patents (PAT) increases the probability of using bank finance by 13.8 percentage points; an increase in the value-weighted sum of patents (PAT*VAL) increases the probability of using bank finance by 23.1 percentage points. However, an increase in usage of bank finance can be attributed to a facilitated access to bank finance as well as to an increase in the demand for bank finance.

When disentangling the usage of bank finance by demand and access, we find that both patenting measures significantly increase the demand for bank finance. An increase by one standard deviation of the unweighted (value-weighted) patent sum increases the

probability of demanding bank finance by 31.9 (24.8) percentage points. However, with respect to the access measure that takes into account only firms with demand for bank finance, we do not find significant effects of patents. Hence, although we find that patents increase the usage of finance, we cannot show that patents indeed improve the access to bank finance, given that a firm has demand. We observe that an important part in the increase of usage of bank finance can be explained by an increase in demand for bank finance of patenting firms.

With regard to R&D, we find that firms with a higher level of R&D have a significantly lower probability of using bank finance. When disentangling the effects of demand and access, we find that these firms exhibit a lower demand for bank finance. At the same time, given that a firm has demand, a firm with higher R&D levels more often faces financial frictions with regard to bank finance. This could indicate that bank finance may be less suitable for R&D intensive firms, which generally exhibit a higher risk of failure, and further, that these firms may anticipate a restricted access to bank finance and therefore less often apply for it. It is conceivable that these firms fall back, e.g., on venture capital finance. In the further analysis of venture capital, we find a significantly higher demand for R&D intensive firms (in the specification with PAT*VAL), while we do not observe significant differences in the use of venture capital.

For the other control variables, we find that larger firms have a significantly higher usage of bank finance (in the specification with PAT*VAL) and a significantly higher demand for bank finance. Further, innovative firms have a higher usage and demand of bank financing (in the specification with PAT*VAL). For the access to bank finance, we find a better access for firms that are part of a larger company and for firms with a high capability utilization, which can be seen as more established firms.

2.5.2.2 Venture Capital Financing

The results for venture capital finance are summarized in Table 2.7. We find very similar, yet less robust results than for bank finance. The estimated coefficients clearly differ between the 2SLS and the OLS estimations. In the demand estimations, the robust Durbin-Wu-Hausman test rejects the null of exogeneity for the variables for patenting

Table 2.6: Bank finance

	Usage				Demand				Access			
	OLS (1)	2SLS (2)	OLS (3)	2SLS (4)	OLS (5)	2SLS (6)	OLS (7)	2SLS (8)	OLS (9)	2SLS (10)	OLS (11)	2SLS (12)
PAT	0.001	0.161**			0.004	0.172**			-0.007	0.217		
	-0.004	-0.073			-0.005	-0.072			-0.011	-0.246		
PAT*VAL			0.000	0.024**			0.001	0.029***			-0.001	0.014
			(0.001)	(0.009)			(0.001)	(0.010)			(0.002)	(0.019)
R&D	-0.001	-0.274***	-0.001	-0.194***	-0.002	-0.249***	-0.002	-0.189***	-0.037*	-0.524**	-0.036*	-0.266***
	(0.001)	(0.092)	(0.001)	(0.050)	(0.002)	(0.091)	(0.002)	(0.057)	(0.021)	(0.241)	(0.021)	(0.094)
SIZE	0.004	0.015	0.004	0.012*	0.007***	0.016**	0.007***	0.014**	0.000	0.002	0.000	0.001
	(0.002)	(0.009)	(0.003)	(0.007)	(0.002)	(0.008)	(0.002)	(0.006)	(0.002)	(0.004)	(0.002)	(0.003)
EXPR	0.002**	-0.003	0.002**	-0.001	0.002***	-0.002	0.002**	-0.001	0.001	-0.001	0.001	0.001
	(0.001)	(0.003)	(0.001)	(0.002)	(0.001)	(0.003)	(0.001)	(0.002)	(0.003)	(0.007)	(0.002)	(0.003)
EDUC	-0.042***	-0.036	-0.041***	-0.035	-0.052***	-0.051	-0.053***	-0.049*	-0.043	0.036	-0.047	0.006
	(0.012)	(0.035)	(0.012)	(0.027)	(0.015)	(0.034)	(0.015)	(0.028)	(0.047)	(0.097)	(0.047)	(0.064)
CORP	0.035	0.097	0.034	0.077	0.045	0.109	0.044	0.093	0.188	0.712*	0.192	0.423**
	(0.041)	(0.077)	(0.041)	(0.063)	(0.048)	(0.081)	(0.048)	(0.071)	(0.130)	(0.381)	(0.130)	(0.186)
INNO	0.002	0.092	0.002	0.068*	0.009	0.084	0.009	0.066*	-0.025	0.110	-0.028	0.048
	(0.006)	(0.057)	(0.006)	(0.035)	(0.008)	(0.055)	(0.008)	(0.039)	(0.025)	(0.120)	(0.025)	(0.057)
CAPA	0.000	0.001	0.000	0.001	0.000	0.001	0.000	0.001	0.001	0.004**	0.001	0.003**
	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)	(0.002)	(0.001)	(0.001)
Constant	0.083***	0.044	0.085***	0.051	0.141***	0.117**	0.142***	0.120**	0.516***	0.199	0.515***	0.353***
	(0.021)	(0.056)	(0.021)	(0.042)	(0.026)	(0.059)	(0.026)	(0.049)	(0.098)	(0.243)	(0.098)	(0.133)
N	2806	2806	2816	2806	2800	2800	2810	2800	487	487	491	487
R-squared	0.012		0.012		0.019		0.019		0.008		0.009	
F-Statistics												
PAT/PAT*VAL	-	9.626***	-	8.013***	-	9.633***	-	8.015***	-	0.978	-	1.574
R&D	-	10.051***	-	11.373***	-	10.082***	-	11.411***	-	7.725***	-	9.573***
DWH test	-	0.000	-	0.000	-	0.000	-	0.000	-	0.000	-	0.009

Notes: The table presents the coefficients from OLS (uneven columns) and 2SLS (even columns) regressions. The unweighted patent count PAT is instrumented by the 2-digit industry average unweighted patent count, the value-weighted patent count PAT*VAL is instrumented by the 2-digit industry average value-weighted and unweighted patent count. The numbers of employees working in R&D are instrumented by the 2-digit industry averages. All standard errors are adjusted for heteroscedasticity. ***, **, * denote that the coefficient is significantly different from zero at a 0.01, 0.05 and 0.10 level.

and R&D, while the null cannot be rejected in the usage specifications (p-values 0.118 and 0.108). For the access regressions in the specification with PAT, the test rejects exogeneity. For the usage and demand regressions, the F-test for joint significance of the instruments is rejected at high significance levels and the F-statistic varies again between 8.02 and 11.41. To summarize, we find evidence that the variables for patenting and R&D are endogenous in the regressions of venture capital financing. The instruments are found to be sufficiently strong in the estimations for usage and demand, while the estimations for access build on few observations and exhibit very low F-statistics for the instruments.

For the usage of venture capital, we find a significant positive effect for the value-weighted sum of patents PAT*VAL, indicating that a higher number of valuable patents increases the probability of using venture capital. An increase by one standard deviation of the weighted patent sum increases the probability of usage by 6.0 percentage points. The unweighted sum of patents, however, is not significant, which might suggest that the value of patents is more important than the pure patent counts. Further, by splitting usage into demand and access, we can clearly identify demand driven effects. A one standard deviation increase of the unweighted (value-weighted) patent sum leads to an increase by 9.8 (8.6) percentage points in the probability of having demand for venture capital. With respect to access to venture capital, we find no significant effects of patents. However, the number of observations that can be considered for estimating access is much smaller than for the usage and demand estimations, resulting in a smaller statistical power.

2.6 Robustness Checks

2.6.1 Nonlinear Estimations of Patent Functions

To predict the types of firms that highly rely on a financial function of patents, we have estimated OLS estimations. Since the dependent variables take values between 1 and 4, we re-estimate the regressions of Table 2.5 with a nonlinear ordered probit model that takes account of the categorical structure of the dependent variable. Table B.3 in Appendix B presents the results. The estimates are very similar to the OLS regressions.

Table 2.7: Venture capital finance

	Usage				Demand				Access			
	OLS (1)	2SLS (2)	OLS (3)	2SLS (4)	OLS (5)	2SLS (6)	OLS (7)	2SLS (8)	OLS (9)	2SLS (10)	OLS (11)	2SLS (12)
PAT	0.003	0.028			0.005	0.053**			-0.008	-1.139		
	(0.003)	(0.019)			(0.004)	(0.026)			(0.014)	(9.892)		
PAT*VAL			0.001	0.007*			0.001	0.010**			-0.002	0.012
			(0.001)	(0.003)			(0.001)	(0.004)			(0.003)	(0.025)
R&D	0.007	0.027	0.007	0.022	0.008	0.039	0.008	0.050*	-0.005	-0.657	-0.004	0.006
	(0.004)	(0.020)	(0.004)	(0.021)	(0.005)	(0.024)	(0.005)	(0.026)	(0.008)	(5.772)	(0.008)	(0.099)
SIZE	0.003*	0.002	0.003*	0.002	0.003	0.001	0.003	0.001	0.011**	0.118	0.011**	0.010
	(0.002)	(0.001)	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)	(0.001)	(0.004)	(0.951)	(0.004)	(0.016)
EXPR	0.000	-0.001	0.000	-0.001	-0.001	-0.001	-0.001	-0.001	0.005	0.056	0.006	0.003
	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.001)	(0.005)	(0.484)	(0.005)	(0.010)
EDUC	0.008	0.001	0.008	0.001	0.015**	0.001	0.015**	0.002	-0.176*	2.377	-0.173*	-0.266
	(0.006)	(0.007)	(0.006)	(0.007)	(0.007)	(0.009)	(0.007)	(0.009)	(0.093)	(22.318)	(0.093)	(0.325)
CORP	0.107**	0.115***	0.107**	0.116***	0.108**	0.124***	0.109**	0.120***	0.264**	-1.427	0.261**	0.342
	(0.043)	(0.044)	(0.043)	(0.043)	(0.045)	(0.046)	(0.045)	(0.046)	(0.101)	(14.796)	(0.101)	(0.213)
INNO	0.013***	-0.004	0.013***	-0.002	0.018***	-0.011	0.018***	-0.014	0.010	0.568	0.011	-0.010
	(0.005)	(0.011)	(0.005)	(0.012)	(0.005)	(0.015)	(0.005)	(0.016)	(0.035)	(5.129)	(0.035)	(0.086)
CAPA	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	-0.010	0.003	0.003
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.002)	(0.120)	(0.002)	(0.003)
Constant	0.002	0.022	0.002	0.020	0.017	0.052**	0.018	0.052**	0.436**	0.066	0.437**	0.435**
	(0.013)	(0.016)	(0.013)	(0.017)	(0.016)	(0.023)	(0.016)	(0.023)	(0.176)	(3.289)	(0.176)	(0.177)
N	2807	2807	2817	2807	2801	2801	2811	2801	106	106	106	106
R-squared	0.051		0.051		0.055		0.055		0.080		0.083	
F-Statistics												
PAT/PAT*VAL	-	9.630***	-	8.015***	-	9.637***	-	8.018***	-	1.141	-	1.478
R&D	-	10.052***	-	11.373***	-	10.082***	-	11.412***	-	3.082*	-	3.178
DWH test	-	0.118	-	0.108	-	0.010	-	0.011	-	0.011	-	0.3728

Notes: The table presents the coefficients from OLS (uneven columns) and 2SLS (even columns) regressions. The unweighted patent count PAT is instrumented by the 2-digit industry average unweighted patent count, the value-weighted patent count PAT*VAL is instrumented by the 2-digit industry average value-weighted and unweighted patent count. The numbers of employees working in R&D are instrumented by the 2-digit industry averages. All standard errors are adjusted for heteroscedasticity. ***, **, * denote that the coefficient is significantly different from zero at a 0.01, 0.05 and 0.10 level.

We find the same firm characteristics that are associated with a higher reliance on the financial function of patents. Only a firm's size is not significant in the regressions for the patent function "protection against imitation".

Further, if the errors for the outcomes are correlated for individual firms, a seemingly unrelated regression that models the joint distribution of the errors would be more efficient (Cameron and Trivedi, 2010). Since a system of linear regressions with identical control variables collapses to equation-by-equation OLS regressions, we estimate a nonlinear bivariate ordered probit model. Table B.4 presents the results. The first two columns refer to the simultaneous estimations of both patent functions with the financial control variables for demand, the next two columns refer to the simultaneous estimations with the financial control variables for usage and the last two columns refer to the simultaneous estimations with the financial control variables for financial constraints. Again, we identify the same type of firms that highly rely on a financial function of patents. As before, SIZE is not significant in the regressions for the patent function "protection against imitation".

2.6.2 3SLS Estimations

For the analysis of the effect of patents on bank financing and venture capital financing (Table 2.6 and Table 2.7) we have estimated 2SLS regressions that take account of the endogeneity of the patenting activity and R&D. Since the errors in the equations may be correlated, we estimate a system of structural equations to simultaneously account for endogeneity and potential error correlations between the equations. The three-stage least-squares estimator of Zellner and Theil (1962) assumes homoscedastic errors that can be correlated across equations. Table B.5 presents the results. Columns 1a to 1d present the estimates for the simultaneous regressions of *Usage* and *Demand* for both financial sources with PAT as a measure for patenting activity, Columns 2a to 2d present the analogue estimates for PAT*VAL. For the 3SLS regressions we cannot include the equation for *Access*, since *Access* is only observed if *Demand*=1, so that the resulting covariance matrix of errors would be singular. The significance levels are very similar to those of the 2SLS regressions. The standard errors are slightly smaller in 3SLS, which

may be explained by the fact that the standard errors in the 2SLS estimation have been corrected for heteroscedasticity.

2.7 Conclusions

This paper investigates the role of patents in the financing of start-up firms in the high-tech and technology-intensive sectors. The theoretical literature on the function of patents has emphasized that besides the traditional functions, such as protection against imitation, patents can also play a financial role in terms of improving the access to external finance. In a first step, we analyze the importance of a financial function in comparison to the traditional patent functions and identify the types of start-ups that highly rely on it. In a second step, we investigate whether patents can indeed improve the access to venture capital and bank finance, using an instrumental-variable approach that takes into account potential endogeneity and reverse causality. We develop a measure for access to finance that takes account of firms' financial demand and considers whether firms that demand a particular type of financing are successful in obtaining it. To measure the patenting activity, we use value-weighted patent counts that are based on the direct valuations by the patent owners.

The analysis of patents in the access to external finance reveals two important findings. First, we find strong evidence for endogeneity of patenting. Not considering endogeneity and reverse causality of patenting results in highly biased estimates. Second, our results indicate that patents significantly increase the probability of using venture capital and bank financing, in particular when patent values are considered. However, it is not clear whether an increase in the usage of external finance can be fully attributed to an improved access to finance or whether part of the increase is due to an increased financial demand of patenting firms. When we use separate dependent variables for demand and access, our findings clearly verify a demand side effect. Patenting significantly increases the probability of demanding venture capital and bank finance, while we cannot prove an effect of patents on the access to venture capital or bank finance.

Our findings emphasize the necessity of further research on the financial role of patents and stress the importance of using precise measures for the access to finance that control for demand effects and considering potential endogeneity issues of patenting. Furthermore, larger sample sizes are needed to overcome the small statistical power and to identify potential effects.

Chapter 3

Global Investment Decisions and Patent Protection: Evidence from German Multinationals

3.1 Introduction

The protection of intellectual property rights has been an important issue on the international policy agenda. The Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS) has raised the concern in the political and economic debate that stronger intellectual property rights (IPR) can slow down economic progress in developing countries by restricting the ability of domestic firms to imitate and benefit from advanced technologies of foreign firms. However, the proponents of stronger IPR argue that this disadvantage could be partially offset by benefits that arise from increasing investments of multinational enterprises. Stronger IPR could encourage multinationals to expand their scale of operations and increase the local manufacture of technologically sophisticated goods (Branstetter et al., 2011).

For IPR reforming countries, the question whether a strengthening of local IPR protection can attract new foreign investors or stimulate the expansion of existing investments is of high importance for assessing the costs and benefits of IPR reforms. The aim of the

present paper is therefore to empirically examine the second argument, i.e., whether IPR protection affects the global investment decisions of multinationals. We thereby focus on patent law and contribute to a better understanding of how strengthening patent protection affects inward FDI in reforming countries. Using a firm-level panel dataset on the universe of German outward FDI, we investigate individual firm-level investment decisions at the extensive and intensive margins. At the extensive margin, we explore the impact of patent protection on the decision where to locate a foreign affiliate. At the intensive margin, we analyze how the strengthening of patent rights affects the size of foreign affiliates and the ownership share held in these affiliates.

For the analysis, we use rich firm-level panel data of German multinationals and their foreign affiliates from the Microdatabase Direct Investment (MiDi) conducted by the Deutsche Bundesbank. MiDi is a comprehensive yearly database that gathers location and balance sheet information on German foreign affiliates and on affiliates of foreign investors in Germany. By law, German firms are required to report yearly on their foreign direct investments when particular thresholds regarding ownership participation and balance sheet totals of foreign affiliates are exceeded. To measure the local strength of patent protection, we use the Ginarte-Park index (Ginarte and Park, 1997; Park, 2008). This index approximates the strength of patent protection across 110 countries between 1960 and 2005. It considers the categories coverage, membership in international treaties, duration of protection, enforcement mechanisms and provisions for loss of patent protection.

To isolate the effect of patent protection, we exploit variation of patent protection across countries and time, as well as variation of the dependence on patent protection across sectors and time. Conditioning on an extensive set of fixed effects, we account for unobserved firm- and country-specific heterogeneity and capture potential omitted variable bias. The key explanatory variable is the interaction term between host countries' patent protection and the sectoral patent dependence of the parent, which allows for nonlinear effects of patent reforms.

Patent reforms in countries with high initial levels of protection are expected to impose different effects than patent reforms in countries with weak or no protection. Similarly,

depending on a country's previous level of economic development, changes in patent law could exert different effects. Therefore, we additionally add triple interaction terms that allow the effect of patent protection to further vary with a country's pre-reform patent protection and level of economic development.

Our empirical analysis shows that patent protection affects the foreign investment decisions of German multinationals in different ways. First, reforms of the patent system positively affect the location decision of German multinationals. This effect is strongest for firms in sectors that highly depend on patent protection. Moreover, significant nonlinear effects in a host country's initial patent protection and economic development are found. After strengthening patent protection, countries with an already sufficient patent protection experience the highest increase in their location advantage. Further, the results show that countries starting from a low level of economic development also disproportionately attract FDI by reforming their patent system. Second, regarding the intensive margin, we find some evidence for a positive effect of patent protection. However, the effect is much weaker than for the location decision. Given that a foreign affiliate is established, changes in patent reforms play a minor role on the size of the affiliate. Third, we find that firms take into account a higher risk of patent infringement by adapting the capital structure of the foreign affiliate: average ownership shares increase significantly after strengthening patent protection.

The paper complements the literature on the relation between IPR and FDI. A rich theoretical literature has investigated the global effect of IPR protection.[1] In a seminal work, Helpman (1993) shows in a dynamic general equilibrium model of two regions, the innovative North and the imitative South, that the latter never benefits from stronger IPR protection. Extensions by Lai (1998) and Branstetter et al. (2006), which allow for endogenous responses in FDI, innovation or imitation activities, provide conditions under which a strengthening of IPR protection increases the industrial development of

[1] Branstetter et al. (2011) provide a detailed discussion of the theoretical literature.

the South. In their models, the total effect depends on whether an increase in northern FDI compensates for the decrease in southern imitation activities.[2]

Previous empirical studies on international trade and FDI mainly relied on aggregated country- or industry-level data and have led to mixed conclusions.[3] However, high correlations between IPR protection and other omitted host country characteristics as well as no time variation constitute common problems of cross-country studies and provide explanations for the ambiguous results.

A recently growing empirical literature uses firm-level data to examine how IPR protection affects the global investment decisions of individual multinationals. The following recent studies are particularly relevant to this work. Branstetter et al. (2011) investigate the impact of patent reforms in 16 countries on the investment behavior of U.S. multinationals and show a positive effect on the intensive margin of FDI, i.e., the size of foreign affiliates. They find that parents that intensively license technologies increase their foreign investments disproportionately. Furthermore, using the same sample, Branstetter et al. (2006) show that patent reforms stimulate the transfer of technology to reforming countries. Using time- and country-specific variations in the Ginarte-Park patent index, Bilir (2011) confirms a positive effect of patent protection on the FDI of U.S. multinationals. She shows that the effect is strongest for firms that are active in sectors with long product lifecycle lengths and therefore rely more on patent protection. Javorcik (2004) finds a positive effect of patent protection on FDI in technologically intensive sectors for transition countries. Moreover, she demonstrates that strong IPR protection encourages multinational enterprises to invest in local manufacture rather than in the distribution of goods.

This paper is also related to the literature that examines how political risk in general influences the capital structure decisions of multinationals. Kesternich and Schnitzer

[2]In this literature, the South can gain access to new technology through FDI or imitation. Yang and Maskus (2001a) additionally allow for licensing as a third channel for technology transfer and show theoretically that stronger IPR can raise technology transfer to the South. Yang and Maskus (2001b) provide empirical evidence that licensing activities are more likely to take place in countries with strong IPR protection.

[3]Maskus (2000) provides a detailed discussion of previous empirical analysis based on aggregated data. See, e.g., Ferrantino (1993), Lee and Mansfield (1996), Maskus and Penubarti (1995), and Smith (1999).

(2010) provide theoretical and empirical evidence that local political risk adversely affects the capital structure of foreign affiliates in terms of ownership. The optimal ownership share decreases with higher political risk, since expected returns are reduced, while the managerial costs of running the affiliate are unaffected.

This paper contributes to the literature in three ways. First, we provide a strong identification strategy that allows for nonlinear effects of patent protection and considers various sources of omitted variable bias. The identification is based on variation in patent protection across countries and time as well as on variation in patent sensitivities across sectors and time. Additionally, we also take into account variation on host countries' previous levels of legal and economic development, which enables us to draw more precise policy recommendations for reforming countries. We show that the identified effects of patent protection are robust to the inclusion of country-time fixed effects, which absorb all observed and unobserved time-varying country characteristics. Second, the paper provides a comprehensive analysis of FDI decisions. It decomposes the various levels of FDI decisions of multinationals, namely decisions on location, size and ownership structure, something which has been missing in the previous analysis.[4] Third, this paper provides the first firm-level evidence on German multinationals. Insights into how German multinationals are affected by international patent protection are particularly interesting because German firms play an important role in international FDI outflows. With a total FDI outflow of 105 billion USD in 2010, Germany is second largest in the ranking of FDI outward countries (UNCTAD, 2011). A systematic analysis of German multinationals has not yet existed.

The rest of the paper is organized as follows. Section 3.2 discusses the empirical strategy and presents the empirical model. Section 3.3 provides a detailed description of the data sources used in the analysis and presents the descriptive statistics. The results are discussed in Section 3.4. Section 3.5 reports various robustness checks and Section 3.6 concludes.

[4]The analysis by Bilir (2011) provides for the first time a joint analysis on the extensive margin (industry-level) and intensive margin (firm-level) of FDI.

3.2 Empirical Specification

3.2.1 Identification

The impact of patent protection on foreign direct investment decisions is investigated along three dimensions: the location decisions of German multinationals, the size of the investment and the ownership structure. Varieties of the following baseline specification will be estimated for the different levels of the investment decision.

$$FDI_{ict} = \beta_1 PAT_{c,t-1} + \beta_2 PAT_{c,t-1} * PATDEP_{it} + \gamma X_{c,t-1} + \delta Y_{i,t} + \eta_i + \eta_c + \eta_t + \lambda_{ict} \tag{3.1}$$

where FDI_{ict} is a measure of the global investment activity of firm i in country c during year t, $PAT_{c,t-1}$ captures the patent protection in country c at year $t-1$, and $PATDEP_{it}$ represents different sectoral measures of firms' sensitivity to patent protection.

To establish a causal effect, different potential issues need to be addressed. Most importantly, one might be concerned that the level of patent protection could be correlated with unobserved host country characteristics that influence FDI decisions, which could lead to omitted variable bias. To guard against omitted variable bias, we condition on an extensive set of fixed effects. Country fixed effects η_c capture time-invariant country characteristics such as legal origin, language and geography (including distance and natural resources). These time-constant heterogeneities are expected to influence foreign direct investment decisions and can simultaneously be correlated with the level of patent protection. Further, time dummies η_t are included to absorb the impact of common shocks that affect host countries in a similar manner over time.

To additionally take into account country-specific dynamics of potential FDI determinants, various time-varying host country covariates $X_{c,t-1}$ are included. We control for changes in the statutory corporate tax rates, changes in the school system (approximating human capital; measured by the share of pupils that progress to secondary school), changes in the GDP per capita (approximating trends in market

attractiveness), and changes in the host country's exports (capturing strategic platform motives). Furthermore, indexes for general rule of law and the overall openness to trade are included to capture general reforms of the legal system and altering trade barriers.[5] All country-specific variables are lagged once.

Moreover, parent fixed effects η_i are included to capture firm-specific heterogeneities, and in particular unobserved firm-specific differences, such as risk aversion or business practices, that are expected to strongly correlate with a firm's investment decisions. Note that parent fixed effects capture fixed industry-specific differences as well as time constant ownership links to holding firms. To capture differences in parent-specific time-varying effects such as different growth rates, we in addition include a parent's productivity measured by the logarithm of the ratio of sales over employees.

A further factor that could interfere with identification is the possibility that patent reforms can be accompanied by simultaneous institutional reforms. Consequently, changes in FDI behavior following patent reforms would then not be fully attributable to a better legal protection of patents. Exploiting variation across reforming countries as well as variation across sectors with varying levels of sensitivity to patent protection allows to isolate the effect of patent reforms from that of other potentially confounding factors.[6] The index of patent protection is therefore interacted with measures of the industry-specific dependence on patent protection. Since not all companies rely equally intensely on patent protection, the influence of patent reforms on a firm's investment decision is expected to be heterogeneous.

We explore two different measures that reflect the sensitivity to patent protection: R&D intensity (R&D) and the perceived effectiveness of patents for protecting inventions

[5]The corporate tax rate data is taken from various issues of the corporate tax guides of PriceWaterhouseCoopers, KPMG, Coopers&Lybrand, Ernst&Young, and information from the International Bureau of Fiscal Documentation (IBFD). Country data on GDP per capita, the school system and exports (exports of goods and services as a share of of GDP) are taken from the World Bank Development Indicator. The indexes on the rule of lae and trade freedom are obtained from the Heritage Foundation. The definitions of the variables are summarized in Table C.1 in Appendix C.

[6]This difference-in-difference type approach can be found, e.g., in Rajan and Zingales (1998), Chor and Manova (2012) and Manova (2013), where interactions between sector-specific measures of financial vulnerability are used to isolate the effect of country-specific financial development. Bilir (2011) uses sector-specific variations in product cycle lengths to strengthen the identification of the effect of patent protection.

(PATEFF). The industry-specific R&D intensity provides continuous time-varying approximations for the sensitivity to patent protection at the parent sector-level. A higher intensity in R&D accompanies a higher rate of innovations, resulting in a greater need to protect inventions against imitations. To directly measure the dependence on the patent system, the industry-specific perception of the effectiveness of patent protection is taken from Cohen et al. (2000). This measure takes into account the relative importance of patents for protecting inventions compared to other protection strategies, such as secrecy.[7] In the related literature, e.g., measures of industry-specific product cycle lengths (Bilir, 2011), technology licensing (Branstetter et al., 2011) and patent usage (Branstetter et al., 2006) have been used to allow for nonlinear effects of patent protection. A detailed description of the measures can be found in Section 3.3.2.

Furthermore, one would expect the effect of strengthening patent protection to depend on the initial level of protection. It could make a difference whether a reform takes place in a country with an already high initial level of patent protection or whether it takes place in a country with a minimal or no protection. The same applies to different levels of economic development. An patent reforming country with a very low level of economic development might not attract FDI in the same manner as a highly developed reforming country. Triple interaction terms ($PAT_{c,t-1} * PATDEP_{it} * Low/High\ Level_c$) allow the effect to further differ according to whether the country falls in the lowest (highest) 25th percentile of patent protection within all included countries (analogue for GDP per capita).[8]

Finally, the main variables of interest are the double and triple interaction terms. The coefficient of $PAT_{c,t-1} * PATDEP_{it}$, β_2 estimates the effect of changes in host countries' strength of patent protection over time on the investment behavior of German multinationals. β_2 is identified from the variation in patent protection across countries,

[7]The perception-based measure PATEFF is taken from a survey of U.S. manufacturing firms. This time constant information refers to the year 1994, so before the changes in patent law that we investigate in this analysis. PATEFF should therefore be clearly exogenous to patent reforms in particular host countries. The measure of R&D intensity refers to German industries. Thereby, national and international German firms are considered. The aggregated information on German firms should be not systematically related to changes in patent protection of particular foreign countries.

[8]The relative position of a country is determined at the first year of the sample. This avoids that a country changes its relative position over time due to other countries' patent reforms or increases in GDP per capita, without implementing own improvements.

the variation in patent protection over time within a country, and the variation in patent sensitivity across and within sectors. The coefficients of the triple interaction terms are additionally identified from variation in the initial levels of patent protection and economic development across countries.

3.2.2 Estimating Equations

Location Decision To investigate the location decision of German multinationals, we follow Javorcik (2004) and inflate the dataset by all observable host countries, such that each parent firm could have invested in each host country within each time period. The number of observations equals the number of parents times the number of host countries in each year. The binary variable y_{ict} equals 1 if parent i holds an affiliate in host country c in year t. We specify the following linear probability model

$$\begin{aligned} Pr(y_{ict} = 1) = \beta_1 PAT_{c,t-1} + \beta_2 PAT_{c,t-1} * PATDEP_{it} + \gamma X_{c,t-1} + \delta Y_{i,t} \\ + \eta_i + \eta_c + \eta_t + \lambda_{ict} \end{aligned} \tag{3.2}$$

where η_i captures parent fixed effects that account for time-invariant firm-specific characteristics, η_c time-constant host country fixed effects and η_t year fixed effects. The vector $X_{c,t-1}$ summarizes time-varying host country covariates (lagged once), $Y_{i,t}$ the time-varying parent-level controls.

A linear probability model has the advantage of not requiring a distributional assumption regarding the firm-specific unobserved effects η_i. An independence assumption on the responses (y_{ic1},...,y_{icT}) conditional on the explanatory variables and the unobserved effect is further not necessary (Wooldridge, 2010). Since the identification is based on an extensive set of fixed effects, many dummies have to be included in the regression. In maximum likelihood estimations of nonlinear models this could introduce an incidental parameters problem, which can result in inconsistent estimations of all coefficients, while in linear regression models the slope estimator is unbiased and consistent (Greene, 2008, p.587). Therefore, a linear probability model is preferable in this setting. Furthermore, linear probability models allow to directly interpret the marginal effects of the interaction

terms, which are of main interest in this study.[9] In a robustness check, the location decision is re-estimated with nonlinear fixed effects models. Standard errors are clustered on the parent-level to account for heteroskedasticity and serial dependence in the firm-level panel data.[10]

Size of Investment For the intensive margin of FDI, we investigate how patent protection influences the size of foreign affiliates, given that a multinational has invested in a specific country. The basic specification takes the form

$$Size_{ijt} = \beta_1 PAT_{c,t-1} + \beta_2 PAT_{c,t-1} * PATDEP_{it} + \gamma X_{c,t-1} + \delta Y_{i,t} + \eta_i + \eta_c + \eta_t + \lambda_{ict}, \tag{3.3}$$

where i indexes the parent, j the foreign affiliate, c the country and t the year. The variable $Size_{ijt}$ contains the alternative size measures *Log(FDI)*, *Log(Sales)* and *Log(Employees)*. In all specifications, we include dummies for the affiliate age and sector.[11]

Ownership Structure In the global investment decision of multinationals, the influence of patent protection on the composition of the FDI is of particular interest. Multinational firms can adapt the ownership structure of their foreign affiliates to respond to country specific risks that affect the expected profitability of their investments. We estimate

$$Ownership_{ijt} = \beta_1 PAT_{c,t-1} + \beta_2 PAT_{c,t-1} * PATDEP_{it} + \gamma X_{c,t-1} + \delta Y_{i,t} + \epsilon Z_{ijct} + \eta_i + \eta_c + \eta_t + \lambda_{ict} \tag{3.4}$$

where $Ownership_{ijt}$ is the share of the affiliate's equity held by the German parent. The vector Z_{ijct} captures time-varying affiliate characteristics that are expected to influence

[9] This is not straightforward in nonlinear models, see Ai and Norton (2003) for a detailed discussion.

[10] Clustering on country-level does not affect the results of the key variables concerning patent protection and leads to the same conclusions.

[11] Unfortunately, direct information on the year of foundation is not available. Instead, we approximate an affiliate's age with the number of years since the affiliate has entered the dataset.

the ownership structure. Following Kesternich and Schnitzer (2010), we include an affiliate's fixed over total assets, log(sales), and profits over total assets as additional control variables. Further, dummies for an affiliate's sector and age are included.

3.3 Data

The empirical analysis requires a time-varying measure of patent protection that ideally covers all potential host countries, proxies for the sectors' sensitivity to patent protection, and detailed firm-level data on multinational activities across countries and time. In the following, the data sources used are described in detail and the descriptive statistics are presented.

3.3.1 Patent Protection Across Countries

Ginarte and Park (1997) provide an index of patent protection, which has been widely used in the literature.[12] That index has been updated by Park (2008) and covers 110 countries for 1960-2005, surveyed every five years. It documents the strength of patent rights in five categories: extent of coverage, membership in international patent agreements, duration of protection, enforcement mechanisms, and provisions for loss of patent protection. The categories are scored with values ranging from 0 to 1 and an unweighted sum is constructed, so that the index varies between 0 and 5 (for details, see Park, 2008; Ginarte and Park, 1997).

Table C.2 in Appendix C summarizes the patent protection across the host countries in the sample for 1996-2006. Across countries, the average patent protection varies between 1.41 (Guyana) and 4.88 (USA). Between the years 1996 and 2006, many countries introduced a minimum protection level or strengthened their existing patent laws, such that the global average protection level increased over time from 2.78 to 3.57. In the entire panel the index has a mean of 3.24 and a standard deviation of 1.03.

[12] See, e.g., Kumar (2001), Javorcik (2004), Branstetter et al. (2006), Falvey et al. (2006), Qian (2007) and Bilir (2011).

For robustness, we also use a perception-based measure of IPR protection provided by the World Economic Forum. This measure is available for 98 countries with yearly values for 2005-2009. A potential disadvantage of this measure is that it covers a relative short time period and does not include observations from the 90s, when major reforms took place (see Section 3.5.3).

3.3.2 Sensitivity to Patent Protection Across Sectors

Two different measures for a firm's sensitivity to patent protection are explored. First, information on the R&D intensity is taken from the Centre for European Economic Research (ZEW). The measure is based on the proportion of expenditures for innovation over total sales and provides a continuous time-varying measure of the R&D intensities of German industries. Firms in industries with high R&D intensities exhibit, on average, a higher rate of innovation, which goes along with a greater need to protect inventions against imitations.

Second, a perception-based measure of the dependence on patent protection is taken from the survey of Cohen et al. (2000). This survey is based on a sample of U.S. manufacturing firms for the year 1994, in which firms were asked how effective they perceived patents to be at protecting their innovation. The important difference with regard to R&D intensity is that some industries, depending on the type of invention, more often prefer not to file a patent application and thereby disclose sensitive information, but to strategically keep inventions secret. However, it has to be assumed that the perceptions of firms from the respective German sector are sufficiently correlated and that the ranking across sectors is relatively stable over time. Otherwise the measure would contain a lot of noise or even no information and the estimated coefficient would be biased towards zero. The measures for the sensitivity to patent protection for the 29 included industries (mainly matched at the 2-digit level of the NACE 1 industry code) are listed in Table C.3 in Appendix C.

3.3.3 German Outward FDI

The analysis is based on the Microdatabase Direct Investment (MiDi) provided by the Deutsche Bundesbank (German Central Bank). It constitutes a comprehensive dataset, since German parents are required by law to report on their foreign investments if certain thresholds on balance-sheet totals and ownership shares are exceeded (Lipponer, 2006). For this research yearly firm-level panel data on German multinationals and their foreign affiliates for the years 1996-2010 were used.

The research interest lies in direct outward FDI, such that observations on outward FDI that constitute ownership chains of dependent affiliates are excluded. Reporting thresholds have been changed several times during the covered time period, influencing the composition of the sampled firms. To harmonize the sample between years, the strictest reporting threshold is considered, such that only parents with a participation share of at least 50 percent and a balance sheet total of 3 million EUR are included.[13] Furthermore, the analysis concentrates on parents from manufacturing sectors, since information on patent sensitivity is mainly available for these sectors. Since the patent protection index is available in five-year intervals, data can be matched for the years 1996, 2001 and 2006. Thereby, 84 of 138 destination countries for German multinational can be matched, covering 89 percent of total outward FDI of the considered multinationals in the sampled years. The final sample comprises 2,726 individual German parents which hold in total 12,152 foreign affiliates in 84 different destination countries (see Table 3.1). Table 3.2 summarizes the descriptive statistics for all variables.

Table 3.1: Sample characteristics

Year	# Parents	# Affiliates	# Destinations
1996	1,342	2,954	39
2001	1,781	4,689	67
2006	1,509	4,509	74
Total	2,726	12,152	84

[13]Before 1999, the reporting threshold was an ownership share of more than 20 percent and a balance sheet total of more than 1 million DM, for 1999-2002 an ownership share of 50 percent or more and a balance sheet total of more than 1 million DM (10-50 percent for more than 10 million DM) and since 2002 an ownership share of 10 percent or more and a balance sheet total of more than 3 million EUR. See Lipponer (2006) for more details.

Table 3.2: Descriptive statistics

Variable	Mean	St Dev	Min	Max
Parent-level				
Productivity	5.78	1.34	0.79	12.71
R&D	3.52	2.41	0.35	8.96
PATEFF	34.96	9.03	12.08	50.20
Affiliate-level				
Ownership	0.93	0.15	0.50	1.00
Log(Sales)	7.99	4.78	-4.60	16.33
Log(FDI)	8.69	1.46	0.15	17.08
Log(Employees)	3.21	3.04	-4.60	11.22
Fixed/Total Assets	0.24	0.25	0.00	1.00
Profitability	0.04	0.14	-1.42	1.18
Country-level				
PAT	3.27	0.99	0.00	4.88
Log(GDPpc)	8.14	1.60	4.16	11.30
Corporate Tax	29.92	8.75	0	60
Schooling	33.81	23.02	0.46	93.49
Exports	43.64	29.69	7.26	229.68
Rule of Law	55.22	22.63	10	90
Trade Openness	66.20	14.68	0	90

Notes: All min (max) values refer to averages of the three smallest (largest) firms. The number of firms for the smallest (largest) category is increased, if the standard devition is equal to zero for the three firms. The definitions of the variables are summarized in Table C.1.

Figure 3.1 presents scatter plots for the dependent variables.[14] The first graph illustrates the relation between patent protection and the logarithm of the number of German affiliates in a host country. There is a positive and convex relation. The better the patent protection, the more German affiliates are localized in a host country. The next three graphs present how the mean of the size measures *Log(Sales)*, *Log(FDI)* and *Log(Employees)* varies with patent protection. Countries with a better patent protection host on average larger affiliates with higher sales amounts. With regard to the number of employees, no clear relation appears. The last graph presents the relation between average ownership shares of foreign affiliates and patent protection. Although high ownership shares can be found in countries at all levels of patent protection, the highest values are

[14]Due to the confidentiality of the data, only information on host countries with affiliates from at least three different parent firms are used for the graphs.

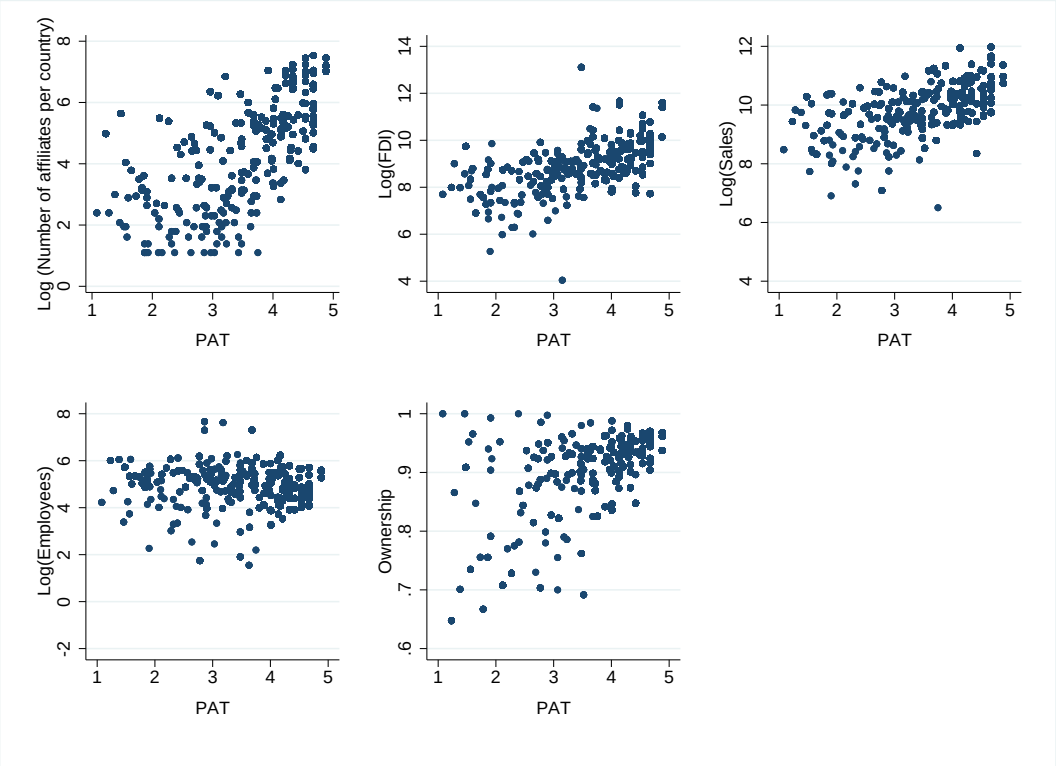


Figure 3.1: Scatter plots of the dependent variables

concentrated in countries with strong protection. To study the above observed patterns more precisely, multivariate regressions are presented in the following.

3.4 Results

The aim of the analysis is to investigate the effect of patent protection on various dimensions of FDI. This section presents the multivariate regressions on the decision where to locate a foreign affiliate and, given that an affiliate has been established, the decisions how much to invest, and how to set the ownership share of the affiliate.

3.4.1 Location Decision

Table 3.3 presents the results for the location decision. The coefficient of PAT in the specification without interactions (Column 1) is positive and significant. A strengthening of patent protection by one standard deviation (1.03) is associated with an on average 1.25 percentage points higher probability of locating a foreign affiliate. Furthermore, GDP per capita, the quality of the schooling system, the connectedness to the world (in terms of exports) and higher trade freedom are also found to significantly attract German FDI, while a higher tax rate reduces the probability of affiliate location.

Since identification is stronger when allowing for nonlinear effects of patent protection, Columns 2 and 3 present interactions between PAT and the measures of patent sensitivity. Both coefficients of the interaction terms are significantly positive and indicate a strong nonlinear relation that increases with the industry-specific sensitivity for patent protection. An increase in patent protection by one standard deviation increases the probability of having located a foreign affiliate by 1.80 percentage points (with PATEFF) and 0.73 percentage points (with R&D) for an average firm. The direct measure of patent sensitivity quantifies a stronger effect of patent protections.

With regard to the parent explanatory variables, we find that a higher productivity of the parent increases the general probability of FDI. This is in line with theoretical predictions that a productivity cut off exists.[15] Further, firms active in industries with high R&D intensities generally less often invest abroad.[16]

[15] See, e.g., Melitz (2003) for the role of firm productivity in international trade and Helpman et al. (2004) for FDI and exports.

[16] Note, that the measure PATEFF is time invariant and is therefore captured in the parent FE effect.

Table 3.3: Location decision

Dependent variable: Location			
	(1)	(2)	(3)
Productivity	0.0102***	0.0110***	0.0105***
	(0.0012)	(0.0014)	(0.0013)
Log(GDPpc)	0.0237***	0.0233***	0.0234***
	(0.0023)	(0.0024)	(0.0023)
Corporate Tax	-0.0003***	-0.0003**	-0.0003***
	(0.0001)	(0.0001)	(0.0001)
Schooling	0.0004***	0.0004***	0.0003***
	(0.0001)	(0.0001)	(0.0001)
Exports	0.0005***	0.0005***	0.0005***
	(0.0001)	(0.0001)	(0.0001)
Rule of Law	-0.0001	-0.0001	-0.0001
	(0.0000)	(0.0000)	(0.0000)
Trade Openness	0.0003***	0.0003***	0.0003***
	(0.0001)	(0.0001)	(0.0001)
PAT	0.0121***	-0.0039	0.0036
	(0.0015)	(0.0030)	(0.0025)
PAT*PATEFF		0.0005***	
		(0.0001)	
PAT*R&D			0.0020***
			(0.0004)
R&D			-0.0078***
			(0.0018)
Observations	284523	261434	275373
Indiv. Parents	2726	2490	2630
Destinations	84	84	84
Adjusted R^2	0.1897	0.1944	0.1929

Notes: Standard errors are clustered by parent firm, with ***, **, * denoting significance at 1%, 5% and 10% levels respectively. The dependent variable is the binary location variable y_{ict} that equals 1 if parent i holds an affiliate in host country c in year t. All specifications include country, year and parent fixed effects.

Table 3.4 summarizes the results for the triple interactions that allow the effect of patent reforms to further vary with a country's initial level of patent protection or economic development. The elasticity to patent reforms significantly differs with the initial level of patent protection. Reforming countries with an already high patent protection level (upper 25 percentile) are able to attract more FDI than countries with a low or middle level of protection. With regard to the initial level of economic development, we observe a U-shaped relation. The previously observed pattern that more patent sensitive firms have a higher elasticity to patent reforms remains robust in all specifications. In comparison to countries with an average initial development level (25 to 75 percentile), we find additional positive effects of strengthening patent protection for low developed countries (lowest 25 percentile) as well as for high developed countries.

3.4.2 Size of Investment

The estimations for the size measures *Log(FDI)*, *Log(Sales)* and *Log(Employees)* are summarized in Table 3.5. Regarding patent protection, the results for the intensive margins of FDI are much weaker than for the extensive margin. In the baseline regressions without interaction terms (Columns 1, 4 and 7) a significant positive effect of patent protection is found for affiliate's sales and employees. When including interaction terms between PAT and patent sensitivity, a significant effect is found with PATEFF for *Log(FDI)*, while the coefficients in the other specifications are not significant. Taken together with the previous results, this suggests that patent protection plays a major role for the location decision, while, given that a multinational has established a foreign affiliate, it seems to play a minor role for the scope of the investment.

Instead, the most important determinant for the intensive margin of FDI is GDP per capita. Given that a firm is located in a specific host country, raises in the GDP per capita significantly increase affiliate size. A host country's tax rates and schooling system are not found to influence an affiliate's size. Similar to PAT, these determinants are found to have major importance for the location decision, but given location, they seem not to influence the decision on the size of the investment. Interestingly, exports are found to have a significant and positive effect on the number of employees, such that platform

Table 3.4: Location decision with heterogeneity in initial host country characteristics

Dependent variable: Location Triple interaction with:	Initial PAT		Initial GDPpc	
	(1)	(2)	(3)	(4)
Productivity	0.0110***	0.0105***	0.0110***	0.0105***
	(0.0014)	(0.0013)	(0.0014)	(0.0013)
Log(GDPpc)	0.0223***	0.0242***	0.0223***	0.0226***
	(0.0023)	(0.0023)	(0.0024)	(0.0023)
Corporate Tax	-0.0003***	-0.0003***	-0.0004***	-0.0004***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Schooling	0.0003***	0.0003***	0.0004***	0.0004***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Exports	0.0005***	0.0005***	0.0004***	0.0004***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Property Rights	-0.0001	-0.0001**	-0.0001**	-0.0001**
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Trade Openness	0.0003***	0.0003***	0.0003***	0.0003***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)
PAT	0.0120***	0.0079***	0.0063**	0.0040*
	(0.0028)	(0.0023)	(0.0027)	(0.0023)
PAT*PATEFF	0.0001		0.0001*	
	(0.0001)		(0.0001)	
PAT*PATEFF*Low Level	0.0000		0.0002***	
	(0.0000)		(0.0000)	
PAT*PATEFF*High Level	0.0003***		0.0004***	
	(0.0000)		(0.0000)	
PAT*R&D		0.0009**		0.0015***
		(0.0004)		(0.0004)
PAT*R&D*Low Level		0.0003**		0.0014***
		(0.0001)		(0.0002)
PAT*R&D*High Level		0.0008***		0.0008***
		(0.0002)		(0.0002)
R&D		-0.0049***		-0.0075***
		(0.0016)		(0.0017)
Observations	261434	275373	261434	275373
Indiv. Parents	2490	2630	2490	2630
Destinations	84	84	84	84
Adjusted R^2	0.1949	0.1931	0.1951	0.1933

Notes: Standard errors are clustered by parent firm, with ***, **, * denoting significance at 1%, 5% and 10% levels respectively. The dependent variable is the binary location variable y_{ict} that equals 1 if parent i holds an affiliate in host country c in year t. All specifications include country, year and parent fixed effects.

motives are found to influence the extensive and intensive margins of FDI. However, with regard to *Log(Sales)* or *Log(FDI)*, no such relation is found. Better terms of trade freedom are associated with higher FDI and more employees in foreign affiliates. Rule of law has a significant negative, but small effect. However, identification in the fixed effect model is based on time variation and since rule of law does not change much over time, this could explain the contradictory results.

3.4.3 Ownership Structure

The analysis on how the capital structure in terms of ownership share reacts to changes in patent protection is presented in Table 3.6. A lack of patent protection goes along with a higher risk of patent infringements and can be seen as a form of political risk. An increase in patent protection, which is associated with a reduction in political risk, leads to an overall increase in the ownership shares of foreign affiliates held by German parents. This confirms the results of Kesternich and Schnitzer (2010) that provide evidence that multinationals adapt the capital structure of their foreign affiliates with respect to local political risk and reduce their ownership shares in high-risk host countries. The results extend the literature by providing first empirical evidence for political risk in terms of patent infringement.

However, the nonlinear effects of patent sensitivity, which would provide a more reliable identification, are not significantly different from zero. One limitation of the analysis that might affect the results is that much variation of the ownership structure is not captured, since only firms with participation shares above the required threshold are required to report on their FDI.[17]

[17]In an alternative estimation, we ignored the harmonization problem of our sample and estimated the determinants of the ownership share with all available observations of foreign affiliates. However, the results did not change.

Table 3.5: Size of foreign affiliates

Dependent variable:	Log(FDI)			Log(Sales)			Log(Employees)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Productivity	0.1045***	0.1127***	0.1125***	-0.4474***	-0.4199***	-0.4367***	-0.5834***	-0.5645***	-0.5751***
	(0.0262)	(0.0274)	(0.0266)	(0.0556)	(0.0575)	(0.0559)	(0.0292)	(0.0307)	(0.0297)
Log(GDPpc)	0.5262***	0.5354***	0.5295***	0.9645***	1.0461***	0.9784***	0.5368***	0.5399***	0.5222***
	(0.1161)	(0.1232)	(0.1160)	(0.1962)	(0.1926)	(0.1982)	(0.0981)	(0.1015)	(0.0986)
Corporate Tax	-0.0040	-0.0058	-0.0050	-0.0090	-0.0066	-0.0073	-0.0029	-0.0046	-0.0034
	(0.0048)	(0.0050)	(0.0048)	(0.0071)	(0.0070)	(0.0070)	(0.0037)	(0.0038)	(0.0037)
Schooling	0.0014	0.0019	0.0022	0.0017	0.0034	0.0029	-0.0006	-0.0004	-0.0001
	(0.0026)	(0.0027)	(0.0026)	(0.0034)	(0.0036)	(0.0035)	(0.0020)	(0.0020)	(0.0020)
Exports	0.0027	0.0038	0.0034	-0.0054	0.0003	-0.0037	0.0059*	0.0074**	0.0061*
	(0.0038)	(0.0041)	(0.0039)	(0.0069)	(0.0064)	(0.0070)	(0.0033)	(0.0033)	(0.0033)
Rule of Law	-0.0070**	-0.0063**	-0.0073**	-0.0136***	-0.0134***	-0.0140***	-0.0076***	-0.0068***	-0.0076***
	(0.0029)	(0.0030)	(0.0029)	(0.0035)	(0.0036)	(0.0035)	(0.0021)	(0.0022)	(0.0022)
Trade Openness	0.0077**	0.0075*	0.0082**	0.0006	0.0024	0.0035	0.0093**	0.0089**	0.0094**
	(0.0037)	(0.0038)	(0.0037)	(0.0052)	(0.0051)	(0.0050)	(0.0037)	(0.0038)	(0.0037)
PAT	0.0364	-0.1092	0.0033	0.1851*	0.0492	0.0475	0.1292**	0.0873	0.0923
	(0.0707)	(0.0925)	(0.1071)	(0.1087)	(0.1449)	(0.1558)	(0.0610)	(0.0839)	(0.1046)
PAT*PATEFF		0.0033**			0.0023			0.0012	
		(0.0015)			(0.0025)			(0.0016)	
PAT*R&D			0.0032			0.0256			0.0102
			(0.0200)			(0.0256)			(0.0195)
R&D			-0.0345			-0.1586			-0.0543
			(0.0884)			(0.1148)			(0.0858)
Observations	10801	10002	10544	11189	10332	10906	11189	10332	10906
Indiv. Parents	2556	2344	2472	2616	2394	2526	2616	2394	2526
Destinations	73	72	73	73	72	73	73	72	73
Adjusted R^2	0.4205	0.4248	0.4215	0.489	0.5045	0.4976	0.6599	0.6632	0.6635

Notes: Standard errors are clustered by parent firm, with ***, **, * denoting significance at 1%, 5% and 10% levels respectively. All specifications include country, year and parent fixed effects. Additionally, dummies for an affiliate's age and sector are included.

Table 3.6: Ownership share of foreign affiliates

Dependent variable: Ownership Share			
	(1)	(2)	(3)
Productivity	-0.0008	-0.0024	-0.0013
	(0.0030)	(0.0032)	(0.0031)
Log(Sales)	0.0032	0.0038	0.0032
	(0.0027)	(0.0030)	(0.0028)
Profitability	-0.0286*	-0.0241	-0.0298*
	(0.0160)	(0.0178)	(0.0163)
Fix/Total Assets	-0.0149	-0.0148	-0.0140
	(0.0155)	(0.0163)	(0.0156)
Log(GDPpc)	-0.0168	-0.0173	-0.0191
	(0.0146)	(0.0153)	(0.0146)
Corporate Tax	-0.0012*	-0.0012	-0.0012*
	(0.0007)	(0.0007)	(0.0007)
Schooling	-0.0004	-0.0004	-0.0003
	(0.0003)	(0.0003)	(0.0003)
Exports	-0.0003	-0.0004	-0.0004
	(0.0005)	(0.0005)	(0.0005)
Rule of Law	-0.0003	-0.0002	-0.0004
	(0.0004)	(0.0004)	(0.0004)
Trade Openness	0.0018***	0.0019***	0.0019***
	(0.0005)	(0.0005)	(0.0005)
PAT	0.0275***	0.0325***	0.0293**
	(0.0083)	(0.0107)	(0.0128)
PAT*PATEFF		-0.0001	
		(0.0002)	
PAT*R&D			-0.0007
			(0.0024)
R&D			0.0069
			(0.0112)
Observations	11187	10330	10904
Indiv. Parents	2615	2393	2525
Destinations	73	72	73
Adjusted R^2	0.3148	0.3137	0.3164

Notes: Standard errors are clustered by parent firm, with ***, **, * denoting significance at 1%, 5% and 10% levels respectively. All specifications include country, year and parent fixed effects. Additionally, dummies for an affiliate's age and sector are included.

3.5 Sensitivity Analysis

3.5.1 Estimation with Country-Year Fixed Effects

To rule out that other changes in a country beyond patent protection are influencing the results, we include time-varying country-year fixed effects. These fixed effects capture all observable and unobservable time-varying components and control for potential omitted time-varying factors at the country level. All changes in the country-specific explanatory variables are adsorbed, including changes in patent protection, such that only the coefficient on the interaction between patent protection and patent sensitivity can be identified in these specifications. Table C.4 to C.6 present the results for location, size and ownership. The results for the interaction terms remain very robust and strengthen our previous findings in the basis estimations. These findings indicate, that no omitted time-varying factors interfere with the estimated effect of patent protection.

3.5.2 Identification of Patent Reforms

To strengthen the identification, different measures of the sensitivity to patent protection have been interacted with PAT, which allows for nonlinear effects of patent protection and provides additional industry-level variation. A concern might still be that the estimated effects could capture reforms of general legal institutions. To verify whether the methodology identifies the effects of changes in patent law alone, we carry out a falsification test and interact PAT with a measure of the industry-specific importance of secrecy for protecting inventions.

Similarly to patent sensitivity, a measure of the effectiveness of secrecy is expected to be positively correlated with industry-specific technological complexity. Yet, additional variation occurs due to industry-specific differences in the patentability of inventions and business practices in protecting innovations. Depending on the type of invention, keeping an invention secret could be preferable to filing a patent and thereby disclosing sensitive information. Most importantly, the degree of reliance on secrecy should not directly depend on formal patent law, which provides no protection for secrecy. If the

effect of PAT is correctly identified from changes in patent law alone, the coefficient of an interaction term between secrecy and PAT should be insignificant. By contrast, a significant coefficient would indicate that changes in general legal institutions are not disentangled and could influence the results.[18]

Table C.7 in Appendix C summarizes the estimations for all FDI dimensions with an interaction term between PAT and a measure of secrecy, which is also taken from the survey of Cohen et al. (2000). Firms that greatly rely on secrecy as a protection strategy do not change their investment behavior due to changes in patent law. For the location decision, where patent protection was found to play the most important role, the interaction term is not significant. Similarly, for all size specifications, no significant effect is found. Only in the ownership regression a weakly significant (at the ten percent level) coefficient is found for the interaction term, indicating that after a reduction of political risk in the form of PAT infringement, parents with a high sensitivity for secrecy increase their ownership share in their affiliates.

3.5.3 Alternative Measurement of IPR Protection

A concern regarding the Ginarte-Park patent protection index may be that it covers mainly law on the books and does not fully capture the de facto strength of enforcement.[19] To account for that potential limitation, we estimate the basis regressions with a perception-based measure of IPR protection (PERC-IPR). This index is provided by the World Economic Forum and is available for 98 countries with yearly values for 2005-2009. It assesses the overall strength of IPR protection at a scale from 1 to 7, with higher values indicating better protection. The index considers patent, copyright and trademark law and is much broader than the Ginarte-Park index, which focuses on patent rights. It has the advantage that it also captures problems in the enforcement of law. A disadvantage of this index is, however, that it covers a relatively short time period that does not include

[18] An alternative explanation for a significant effect could also be that secrecy is, due to the expected correlation with technological complexity, highly correlated with patent sensitivity. However, this would work against the falsification test.

[19] However, enforcement mechanism on the books are considered in the Ginarte-Park index.

observations from the 90s. Consequently, important variation is missing, which could weaken the identification.

Appendix Tables C.8 - C.10 replicate the baseline results with the perception-based IPR index. The underlying firm-level sample covers the years 2006-2010, since the host country variables are lagged once. In the location decision, the results for PERC-IPR are similar to the estimations with the Ginarte-Park index. The coefficients of the interaction terms between PERC-IPR and the patent sensitivity measures are positive and significant. In the size regressions, the coefficients of PERC-IPR and its interaction terms are, similar to the estimations with the Ginarte-Park index, mainly not significant. For ownership, the general positive effect of patent protection is confirmed only in the specification with the interaction between PERC-IPR and R&D. However, the effect is smaller for R&D intensive firms. The net effect after an increase in the PERC-IPR index by one unit is an increase of 0.75 percentage points in the ownership share for the average parent. R&D intensive firms seem to be more cautious in increasing their ownership shares after a strengthening of IPR protection.

3.5.4 Nonlinear Estimation of the Location Decision

In the baseline specification, the location decision is estimated with a linear probability model. This has the advantage that no additional assumptions regarding the unobserved effect η_i and the responses $(y_{ic1},...,y_{icT})$ are necessary and an incidental parameter problem that can occur in a maximum likelihood estimation with an extensive set of dummy variables is avoided. However, as a robustness check, the location decision is re-estimated with a nonlinear conditional logit model, which takes into account the binary nature of the dependent variable. Table C.11 summarizes the results, whereby estimations without country fixed effects (Columns 1-3) and with country fixed effects (Columns 4-6) are presented to assess the severity of any potential incidental parameter problem.

In the specifications without country fixed effects, strengthening patent protection has a positive and significant effect on the probability of locating a foreign affiliate in a reforming country. In contrast to the linear probability estimations (see Table 3.3), the

coefficients of PAT remain positive and significant when interaction terms are included. For all interaction terms, we find positive effects. In the specifications with country fixed effects, we find a positive effect of PAT in the basic specification without interaction terms and a significant positive effect for the interaction with patent effectiveness.

Comparing the results for the host country controls reveals how important country fixed effects are for the identification, since many coefficients change sign when country fixed effects are included. Since the incidental parameter problem is very likely with the extensive set of fixed effects, our preferred estimation model is the linear probability model.

3.6 Conclusions

The present paper analyzes how national patent protection influences various levels in the global investment decisions of German multinationals. In particular, we show that patent protection is a significant factor in attracting technologically sophisticated FDI, since strengthening patent protection increases the probability of locating a foreign affiliate in a reforming country, especially so for R&D intensive and firms that are sensitive to patent protection. This has important policy implications for host countries, as the attraction of FDI can contribute to technology spillovers and foster domestic growth.

Moreover, we show that the effect of patent reforms differs with a host country's pre-reform characteristics. With regard to the initial level of patent protection, we find the strongest effects for countries with an already sufficient pre-reform patent protection. Evidence that a too high patent protection could distort FDI has not been found. With regard to the initial level of economic development, we find the effect of patent reforms is significantly positive at all stages of economic development. However, reforming countries with a relatively high level of economic development exhibit stronger effects of legal reforms and are hence able to attract FDI more successfully than countries with an average economic development. For less developed countries, also disproportional positive effects of patent protection are found. How the effect of patent reforms interacts with

pre-reform country characteristics should be of interest for policy makers that need to forecast future FDI inflows to be able to assess the benefits of patent reforms.

Regarding the size of a foreign affiliate, we identify circumstances under which patent reforms significantly increase the size of affiliates. However, the results are much weaker than for the location decision. Given that an affiliate is established in a country, the effect of patent protection is found to play a minor role for the size of an investment. For the capital structure of multinational firms, we find that a stronger patent protection results in higher ownership shares held by the German parent. This is an important finding, since a higher share of ownership is associated with lower agency costs and higher incentives to transfer technology.

Appendices

A Appendix to Chapter 1

Table A.1: Definition of variables

Variable	Definition
Firm-level	
Age 0-7	Firm has been established after transition (after 1998). BEEPS 2005 (s1a)
Age 14+	Firm has been established before transition (before 1991). BEEPS 2005 (s1a)
Foreign	Largest shareholder is a foreign company. BEEPS 2005 (q4aa)
Privatized	Firm has been established through privatization of a state-owned firm. BEEPS 2005 (q5a)
State-owned	Legal status of company is either state/ municipal/ district-owned, corporatised state-owned or other state-owned enterprise. BEEPS 2005 (s2a)
Small	Firm has less than 50 employees. BEEPS 2005 (s4b)
Transparency	Following Brown et al. (2009) this variable is based on the usage of international accounting standards (q48) and external auditors. It equals 0 if the firm does not use international accounting standards or external auditors, 1 if the firms uses one of the two and 2 if both are used. BEEPS 2005 (q48, q49)
Profits	Firm has realized positive profits in 2003. BEEPS 2005 (q59b)
Capacity	Output in comparison with the maximum output possible. BEEPS (q65a1)
Perceived Competition	Firms are asked to answer the hypothetical question, how customers would react if the firm raised the price of the main product or service by ten percent. It varies from 1 (customer would continue to buy) to 4 (many of the costumers would buy from competitors instead). BEEPS 2005 (q11)
Investment	Firm has acquired new production technology over the last 36 months. BEEPS 2005 (q61a)
Sector dummies	More than 50 percent of the sales of a company comes from this sector. The majority of the firms operates in a single sector. The sectors are mining and quarrying (sector 1), construction (sector 2), manufacturing (sector 3), wholesale, retail and repairs (sector 4), real estate, renting and business services (sector 5), hotels and restaurants (sector 6) and others (sector 7).
Country-level	
Log(GDPpc)	Logarithm of GDP per capita (current US$). Average values for the years 2001-2003. Source: World Bank
Inflation	Inflation, consumer prices (annual percentage). Average values for the years 2001-2003. Source: World Bank
Foreign Bank Assets	Asset share of foreign-owned banks (in percentage). Average values for the years 2001-2003. Source: EBRD (2005b)
Creditor Rights	The index measures the degree to which collateral and bankruptcy laws protect the rights of borrowers and lenders and thus facilitate lending. 2005 value (earlier values not available). Source: World Bank: Doing Business, Getting Credit
Enforcement	Logarithm of time (in days) to resolve a dispute, counted from the moment the plaintiff files the lawsuit in court until payment. This includes both the days when actions take place and the waiting periods in between. 2005 values (earlier values not available). Source: World Bank, Doing Business, Enforcing Contracts
Information Sharing	Based on information from the Doing Business in 2006 report (World Bank, 2006), Brown et al. (2009b) compute for each country and year one index for private credit bureaus and one for public credit registries that account for the existence and coverage of these institutions. The maximum value of both indexes is taken to approximate the level of information sharing. Average values for the years 2001-2003. Source: Brown et al. (2009b)
Bank Concentration	Assets of the three largest banks as a share of assets of all commercial banks. Average values for the years 2001-2003. Source: Beck et al. (2010)

Table A.2: Alternative exclusion restrictions

	Instruments: Perceived Competition				Instruments: Perceived Competition and Subsidy			
	Access (1a)	Demand (1b)	Access (2a)	Demand (2b)	Access (3a)	Demand (3b)	Access (4a)	Demand (4b)
Age 0-7	-0.036***	0.028	-0.036***	0.026	-0.035***	0.029	-0.035***	0.027
	(0.012)	(0.019)	(0.013)	(0.018)	(0.012)	(0.020)	(0.012)	(0.018)
Age 14+	-0.023	0.007	-0.024	0.017	-0.022	0.007	-0.023	0.016
	(0.018)	(0.019)	(0.017)	(0.017)	(0.017)	(0.019)	(0.017)	(0.018)
Foreign	0.044*	-0.125***	0.039	-0.128***	0.045*	-0.124***	0.041*	-0.127***
	(0.026)	(0.027)	(0.025)	(0.026)	(0.026)	(0.027)	(0.024)	(0.026)
State-owned	-0.060	-0.169***	-0.065	-0.177***	-0.055	-0.188***	-0.055	-0.199***
	(0.048)	(0.038)	(0.058)	(0.038)	(0.046)	(0.036)	(0.047)	(0.037)
Privatized	0.009	-0.002	0.026	0.009	0.009	-0.001	0.026	0.008
	(0.016)	(0.019)	(0.021)	(0.022)	(0.016)	(0.019)	(0.020)	(0.022)
Small	-0.142***	-0.070***	-0.140***	-0.063***	-0.138***	-0.067***	-0.134***	-0.059***
	(0.021)	(0.015)	(0.031)	(0.018)	(0.017)	(0.016)	(0.018)	(0.018)
Transparency	0.068***	0.025***	0.071***	0.031***	0.067***	0.024***	0.067***	0.029**
	(0.015)	(0.009)	(0.017)	(0.012)	(0.014)	(0.009)	(0.012)	(0.012)
Profits	0.122***	-0.014	0.111***	-0.027	0.120***	-0.011	0.107***	-0.023
	(0.026)	(0.019)	(0.029)	(0.020)	(0.024)	(0.019)	(0.022)	(0.020)
Capacity	0.001**	-0.002***	0.001*	-0.002***	0.001**	-0.002***	0.001**	-0.002***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Sector 2	0.061	-0.149**	0.049	-0.139**	0.062	-0.148**	0.051	-0.136**
	(0.060)	(0.067)	(0.063)	(0.066)	(0.058)	(0.069)	(0.059)	(0.068)
Sector 3	0.064	-0.112*	0.047	-0.119**	0.065	-0.113*	0.049	-0.119*
	(0.064)	(0.061)	(0.067)	(0.060)	(0.062)	(0.063)	(0.064)	(0.062)
Sector 4	0.078	-0.192***	0.073	-0.181***	0.079	-0.190***	0.074	-0.176***
	(0.052)	(0.064)	(0.053)	(0.063)	(0.051)	(0.066)	(0.051)	(0.064)
Sector 5	0.059	-0.295***	0.063	-0.280***	0.063	-0.294***	0.069	-0.276***
	(0.058)	(0.076)	(0.056)	(0.074)	(0.055)	(0.079)	(0.051)	(0.077)
Sector 6	0.096**	-0.318***	0.101**	-0.307***	0.098**	-0.314***	0.103**	-0.298***
	(0.045)	(0.058)	(0.045)	(0.057)	(0.043)	(0.060)	(0.042)	(0.058)
Sector 7	0.041	-0.195***	0.036	-0.184***	0.043	-0.200***	0.040	-0.187**
	(0.060)	(0.072)	(0.061)	(0.071)	(0.057)	(0.076)	(0.056)	(0.073)
Log(GDPpc)			-0.012	-0.030			-0.010	-0.034
			(0.024)	(0.026)			(0.022)	(0.026)
Inflation			0.000	0.003**			0.000	0.003**
			(0.001)	(0.001)			(0.001)	(0.001)
Foreign Banks			0.001	0.000			0.001	0.000
			(0.001)	(0.001)			(0.001)	(0.001)
Creditor Rights			0.012	0.003			0.011*	0.003
			(0.007)	(0.006)			(0.006)	(0.006)
Information Sharing			0.009	0.008			0.008	0.007
			(0.007)	(0.009)			(0.006)	(0.009)
Enforcement			0.064	0.021			0.061	0.021
			(0.046)	(0.053)			(0.045)	(0.051)
Bank Concentration			-0.109	-0.046			-0.104	-0.039
			(0.100)	(0.112)			(0.091)	(0.110)
Perceived Competition		0.020***		0.020**		0.020***		0.020**
		(0.008)		(0.008)		(0.007)		(0.008)
Subsidy						0.102***		0.121***
						(0.025)		(0.022)
Country FE	Yes		No		Yes		No	
Constant	Yes		Yes		Yes		Yes	
Number of Observations	5689		5689		5689		5689	
ρ	-0.716***		-0.702		-0.759***		-0.789***	
p_ρ	0.005		0.138		0.000		0.002	

Notes: The table presents marginal effects evaluated at the mean from probit regressions with sample selection. The dependent variable in the outcome regression is access to credit, while demand for credit is the dependent variable in the selection equation. Standard errors are clustered on country-level and are reported in parenthesis. In the first two specifications, the instrument in the selection equations is *perceived competition*. In the last two specifications we follow Popov and Udell (2012) and use *perceived competition* and *subsidy* as instruments. Sector coding: 1 mining and quarrying, 2 construction, 3 manufacturing, 4 wholesale, retail and repairs, 5 real estate, renting and business services, 6 hotel and restaurants, 7 others. The left out category for age is *age 8-13* (firms founded during transition), for nationality privately-owned firms and mining and quarrying for sectors. ρ is the correlation between the error terms. ***, **, * denote that the marginal effect is significantly different from zero at a 0.01, 0.05 and 0.10 level.

Table A.3: Heckman two-step estimator

	Access (1a)	Demand (1b)	Access (2a)	Demand (2b)
Age 0-7	-0.064***	0.029*	-0.061***	0.026*
	(0.023)	(0.015)	(0.021)	(0.015)
Age 14+	-0.029	0.007	-0.034	0.015
	(0.023)	(0.017)	(0.022)	(0.016)
Foreign	0.117**	-0.128***	0.093**	-0.129***
	(0.048)	(0.025)	(0.046)	(0.024)
State-owned	0.033	-0.165***	0.001	-0.170***
	(0.061)	(0.029)	(0.061)	(0.029)
Privatized	0.002	0.000	0.017	0.011
	(0.028)	(0.021)	(0.027)	(0.021)
Small	-0.135***	-0.069***	-0.150***	-0.060***
	(0.030)	(0.016)	(0.027)	(0.016)
Transparency	0.068***	0.021*	0.074***	0.029***
	(0.016)	(0.011)	(0.016)	(0.011)
Profits	0.156***	-0.022	0.148***	-0.033*
	(0.026)	(0.018)	(0.025)	(0.018)
Capacity	0.002***	-0.002***	0.002**	-0.002***
	(0.001)	(0.000)	(0.001)	(0.000)
Sector 2	0.137	-0.145*	0.107	-0.137*
	(0.095)	(0.084)	(0.088)	(0.082)
Sector 3	0.113	-0.110	0.094	-0.118
	(0.090)	(0.075)	(0.084)	(0.074)
Sector 4	0.175*	-0.181**	0.151*	-0.173**
	(0.096)	(0.080)	(0.090)	(0.079)
Sector 5	0.211*	-0.283***	0.181*	-0.271***
	(0.115)	(0.084)	(0.109)	(0.083)
Sector 6	0.294**	-0.308***	0.264**	-0.299***
	(0.122)	(0.084)	(0.117)	(0.084)
Sector 7	0.130	-0.188**	0.106	-0.180**
	(0.099)	(0.083)	(0.092)	(0.082)
Investment		0.042***		0.035**
		(0.014)		(0.014)
Perceived Competition		0.021***		0.022***
		(0.006)		(0.006)
Log(GDPpc)			-0.006	-0.028**
			(0.019)	(0.013)
Inflation			-0.000	0.003***
			(0.001)	(0.001)
Foreign Banks			0.001**	0.000
			(0.000)	(0.000)
Creditor Rights			0.013**	0.004
			(0.006)	(0.004)
Information Sharing			0.008	0.009**
			(0.007)	(0.005)
Enforcement			0.073**	0.015
			(0.030)	(0.023)
Bank Concentration			-0.113	-0.052
			(0.069)	(0.052)
Country FE	Yes		No	
Constant	Yes		Yes	
R-squared				
Number of Observations	5689		5689	
Inverse Mills' Ratio	-0.607***		-0.499***	

Notes: The table presents marginal effects evaluated at the mean from the Heckman two-step estimation for access to credit. The dependent variable in the outcome regression is access to credit, while demand for credit is the dependent variable in the selection equation. Standard errors are clustered on country-level and are reported in parenthesis. Sector coding: 1 mining and quarrying, 2 construction, 3 manufacturing, 4 wholesale, retail and repairs, 5 real estate, renting and business services, 6 hotel and restaurants, 7 others. The left out category for age is *age 8-13* (firms founded during transition), for nationality privately-owned firms and mining and quarrying for sectors. ***, **, * denote that the marginal effect is significantly different from zero at a 0.01, 0.05 and 0.10 level.

Table A.4: Standard errors clustered on industry-country-level

	Probit Usage (1)	Probit Usage (2)	Probit Access (3)	Probit Access (4)	Probit with Selection Access (5a)	Probit with Selection Demand (5b)	Probit with Selection Access (6a)	Probit with Selection Demand (6b)
Age 0-7	-0.013	-0.016	-0.040**	-0.042**	-0.035***	0.031*	-0.035***	0.028*
	(0.018)	(0.019)	(0.018)	(0.019)	(0.013)	(0.018)	(0.014)	(0.017)
Age 14+	-0.012	-0.007	-0.029	-0.029	-0.022	0.007	-0.023*	0.018
	(0.017)	(0.017)	(0.019)	(0.019)	(0.014)	(0.018)	(0.014)	(0.017)
Foreign	-0.096***	-0.098***	0.019	0.015	0.046**	-0.125***	0.041*	-0.128***
	(0.027)	(0.026)	(0.034)	(0.034)	(0.023)	(0.027)	(0.023)	(0.025)
State-owned	-0.202***	-0.204***	-0.150***	-0.154***	-0.051	-0.163***	-0.054	-0.173***
	(0.034)	(0.033)	(0.049)	(0.047)	(0.034)	(0.034)	(0.035)	(0.033)
Privatized	0.003	0.031	0.009	0.037	0.009	0.002	0.025	0.011
	(0.023)	(0.029)	(0.025)	(0.029)	(0.018)	(0.020)	(0.020)	(0.022)
Small	-0.206***	-0.191***	-0.216***	-0.210***	-0.136***	-0.063***	-0.132***	-0.056***
	(0.020)	(0.024)	(0.017)	(0.018)	(0.014)	(0.019)	(0.014)	(0.021)
Transparency	0.082***	0.092***	0.099***	0.105***	0.066***	0.022*	0.066***	0.029***
	(0.013)	(0.013)	(0.015)	(0.013)	(0.011)	(0.011)	(0.010)	(0.011)
Profits	0.096***	0.075***	0.154***	0.136***	0.118***	-0.020	0.106***	-0.033*
	(0.021)	(0.022)	(0.028)	(0.027)	(0.021)	(0.018)	(0.021)	(0.019)
Capacity	-0.001***	-0.001***	0.000	0.000	0.001**	-0.002***	0.001**	-0.002***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Sector 2	-0.034	-0.035	0.056	0.043	0.062	-0.155**	0.050	-0.142**
	(0.081)	(0.080)	(0.080)	(0.084)	(0.054)	(0.067)	(0.057)	(0.070)
Sector 3	-0.016	-0.033	0.066	0.041	0.064	-0.122**	0.047	-0.126*
	(0.079)	(0.082)	(0.085)	(0.089)	(0.062)	(0.059)	(0.063)	(0.064)
Sector 4	-0.058	-0.052	0.067	0.064	0.079	-0.190***	0.073	-0.177***
	(0.078)	(0.079)	(0.079)	(0.082)	(0.054)	(0.064)	(0.055)	(0.067)
Sector 5	-0.170**	-0.157**	0.004	0.016	0.063	-0.295***	0.068	-0.277***
	(0.072)	(0.077)	(0.088)	(0.089)	(0.054)	(0.067)	(0.053)	(0.073)
Sector 6	-0.149*	-0.139	0.062	0.074	0.098**	-0.315***	0.102**	-0.301***
	(0.082)	(0.085)	(0.081)	(0.082)	(0.043)	(0.071)	(0.043)	(0.076)
Sector 7	-0.098	-0.091	0.011	0.008	0.044	-0.198***	0.039	-0.184***
	(0.076)	(0.078)	(0.085)	(0.088)	(0.057)	(0.066)	(0.058)	(0.069)
Log(GDPpc)		-0.036		-0.025			-0.011	-0.028
		(0.028)		(0.027)			(0.016)	(0.020)
Inflation		0.003**		0.001			0.000	0.003**
		(0.001)		(0.001)			(0.001)	(0.001)
Foreign Banks		0.001		0.001*			0.001**	0.000
		(0.001)		(0.001)			(0.000)	(0.000)
Creditor Rights		0.015**		0.017**			0.011**	0.004
		(0.008)		(0.008)			(0.005)	(0.005)
Information Sharing		0.017*		0.014			0.008	0.010
		(0.009)		(0.009)			(0.005)	(0.006)
Enforcement		0.073		0.092			0.060*	0.018
		(0.057)		(0.057)			(0.034)	(0.037)
Bank Concentration		-0.149		-0.158			-0.104	-0.054
		(0.134)		(0.122)			(0.070)	(0.092)
Investment						0.055***		0.047***
						(0.013)		(0.014)
Perceived Competition						0.021***		0.021***
						(0.006)		(0.006)
Country FE	Yes	No	Yes	No	Yes	Yes	No	No
Constant	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.086	0.060	0.132	0.102				
Number of Observations	5689	5689	3859	3859	5689		5689	
ρ					-0.784***		-0.803***	

Notes: The table presents the marginal effects evaluated at the mean from the regressions of usage of credit (column 1-2) and access to credit (column 3-6). Standard errors are clustered on industry-country-level and are reported in parenthesis. Sector coding: 1 mining and quarrying, 2 construction, 3 manufacturing, 4 wholesale, retail and repairs, 5 real estate, renting and business services, 6 hotel and restaurants, 7 others. The left out category for age is *age 8-13* (firms founded during transition), for nationality privately-owned firms and mining and quarrying for sectors. The correlation between the error terms ρ is indirectly estimated through atanh ρ. ***, **, * denote that the marginal effect is significantly different from zero at a 0.01, 0.05 and 0.10 level.

B Appendix to Chapter 2

Table B.1: Industry classifications within industry groups

Industry group	WZ2008 industry code
Superior technology manufacturing	20.20, 21.10, 21.20, 24.46, 25.40, 26.11, 26.20, 26.30, 26.40, 26.51, 26.60, 30.30, 30.40, 32.50
High technology manufacturing	20.13, 20.14, 20.16, 20.17, 20.41, 20.51, 20.53, 20.59, 22.11, 22.19, 23.19, 26.70, 27.11, 27.12, 27.20, 27.40, 27.90, 28.11, 28.23, 28.24, 28.29, 28.30, 28.41, 28.49, 28.92, 28.99, 29.10, 29.31, 29.32, 30.20
Technology-intensive services	61.1, 62 (without 62.01), 63.1, 71.1, 72.1
Software supply and consultancy	62.01
Non-high-tech manufacturing	10.3 (without superior technology manufacturing and high technology manufacturing)
Skill-intensive services	69.1, 70.2, 72.2, 73.1

Table B.2: Definition of variables

Variable	Definition
Financial Variables	
Usage-Bank	Dummy=1 if firm uses debt financing.
Usage-VC	Dummy=1 if firm uses venture capital financing.
FC-Bank	Dummy=1 if firm has experienced financial constraints in debt financing.
FC-VC	Dummy=1 if firm has experienced financial constraints in venture capital financing.
Demand-Bank	Dummy=1 if debt financing is used or financial frictions in debt financing have been experienced.
Demand-VC	Dummy=1 if venture capital financing is used or financial frictions in venture capital financing have been experienced.
Access-Bank	Dummy=1 if debt financing is used; =0 if (1) no debt financing is used although firm has demand for it or (2) if debt financing is used, but financial frictions in debt financing still have been experienced.
Access-VC	Dummy=1 if venture capital financing is used; =0 if (1) no venture capital financing is used although firm has demand for it or (2) if venture capital financing is used, but financial frictions in venture capital financing still have been experienced.
Patent Variables	
DPAT	Dummy=1 if number of granted patents of company or founder is nonnegative.
PAT	Number of granted patents of company or founder. Variable is truncated at 22.
VAL	Firm-specific evaluation of the importance of patents for protecting its own competitive advantage (scale from 1 "unimportant" to 5 "very important")
PAT*VAL	Interaction term between the number of granted patents (truncated at 22) and the firm-specific evaluation of the importance of patents for protecting its own competitive advantage (scale from 1 "unimportant" to 5 "very important").
Patent Functions	
Imitation	Firm-specific evaluation of the importance of the patent function "protection against imitation" (scale from 1 "unimportant" to 5 "very important").
Finance	Firm-specific evaluation of the importance of the patent function "improving access to finance" (scale from 1 "unimportant" to 5 "very important").
Licensing	Firm-specific evaluation of the importance of the patent function "obtaining revenues from royalties" (scale from 1 "unimportant" to 5 "very important").
Negotiation	Firm-specific evaluation of the importance of the patent function "improving position in negotiations" (scale from 1 "unimportant" to 5 "very important").
Infringement	Firm-specific evaluation of the importance of the patent function "avoiding patent infringement suits" (scale from 1 "unimportant" to 5 "very important").
Reputation	Firm-specific evaluation of the importance of the patent function "improving firm reputation" (scale from 1 "unimportant" to 5 "very important").
Control Variables	
SIZE	Number of full-time employees.
EXPR	Industry experience of the founder (in years).
EDUC	Dummy=1 if founder has a university degree.
INNO	Variable indicates whether a firm has introduced a market innovation since foundation at the regional market (=1), national market (=2) or worldwide (=3). Else, it equals zero.
CAPA	Current degree of capacity utilization (in percent).
R&D	Number of employees in R&D.
CORP	Dummy=1 if firm is part of another corporation.

Table B.3: Functions of patents (ordered probit)

	Protection from Imitation			Improving Access to Finance		
	(1)	(2)	(3)	(4)	(5)	(6)
SIZE	0.010	0.009	0.010	0.004	0.003	0.004
	(0.010)	(0.009)	(0.010)	(0.005)	(0.005)	(0.005)
EXPR	-0.004	-0.004	-0.003	0.000	0.000	0.001
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
EDUC	-0.323**	-0.319**	-0.276*	-0.006	0.005	0.019
	(0.147)	(0.146)	(0.146)	(0.134)	(0.133)	(0.134)
CORP	0.993**	0.985**	0.984**	-0.433	-0.464	-0.372
	(0.398)	(0.397)	(0.394)	(0.386)	(0.387)	(0.384)
INNO	0.083	0.083	0.092*	0.096*	0.097*	0.106**
	(0.054)	(0.054)	(0.054)	(0.051)	(0.051)	(0.051)
CAPA	-0.001	-0.001	-0.001	-0.007***	-0.007***	-0.007***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
R&D	0.013	0.013	0.016	0.002	0.002	0.020
	(0.037)	(0.036)	(0.034)	(0.028)	(0.029)	(0.027)
Demand-Bank	-0.070			-0.070		
	(0.156)			(0.142)		
Demand-VC	0.106			0.538***		
	(0.198)			(0.180)		
Usage-Bank		-0.002			-0.041	
		(0.199)			(0.170)	
Usage-VC		0.146			0.605***	
		(0.239)			(0.207)	
FC-Bank			-0.102			-0.037
			(0.185)			(0.180)
FC-VC			0.134			0.628**
			(0.268)			(0.296)
Observations	330	330	333	328	328	331

Notes: The table presents the coefficients from ordered probit regressions of the importance of the patent functions "protection from imitation" and "improving access to finance". All standard errors are adjusted for heteroscedasticity. ***, **, * denote that the coefficient is significantly different from zero at a 0.01, 0.05 and 0.10 level.

Table B.4: Functions of patents (bivariate ordered probit)

	(1)		(2)		(3)	
	Imitation (1a)	Finance (1b)	Imitation (2a)	Finance (2b)	Imitation (3a)	Finance (3b)
SIZE	0.014	0.004	0.013	0.003	0.014	0.004
	(0.015)	(0.005)	(0.015)	(0.005)	(0.015)	(0.005)
EXPR	-0.003	0.001	-0.003	0.001	-0.003	0.002
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
EDUC	-0.319**	0.015	-0.316**	0.026	-0.272*	0.041
	(0.148)	(0.134)	(0.147)	(0.133)	(0.147)	(0.134)
CORP	0.925**	-0.424	0.919**	-0.455	0.919**	-0.363
	(0.399)	(0.383)	(0.398)	(0.384)	(0.396)	(0.381)
INNO	0.074	0.089*	0.074	0.090*	0.083	0.099*
	(0.054)	(0.051)	(0.054)	(0.051)	(0.054)	(0.051)
CAPA	-0.001	-0.007***	-0.001	-0.008***	-0.001	-0.008***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
R&D	0.009	0.003	0.01	0.003	0.011	0.022
	(0.039)	(0.028)	(0.039)	(0.029)	(0.037)	(0.027)
Demand-Bank	-0.079	-0.067				
	(0.155)	(0.142)				
Demand-VC	0.097	0.538***				
	(0.196)	(0.180)				
Usage-Bank			-0.017	-0.044		
			(0.198)	(0.170)		
Usage-VC			0.131	0.606***		
			(0.236)	(0.206)		
FC-Bank					-0.102	-0.029
					(0.185)	(0.181)
FC-VC					0.136	0.631**
					(0.268)	(0.295)
Observations	327		327		330	

Notes: The table presents the coefficients from bivariate ordered probit regressions. The determinants for the importance of the patent functions "protection from imitation" and "improving access to finance" are jointly estimated for each alternative financial measure. All standard errors are adjusted for heteroscedasticity. ***, **, * denote that the coefficient is significantly different from zero at a 0.01, 0.05 and 0.10 level.

Table B.5: 3SLS regressions

	(1)				(2)			
	Bank Financing		Venture Capital		Bank Financing		Venture Capital	
	Usage (1a)	Demand (1b)	Usage (1c)	Demand (1d)	Usage (2a)	Demand (2b)	Usage (2c)	Demand (2d)
PAT	0.161**	0.172***	0.028*	0.053***				
	(0.067)	(0.065)	(0.014)	(0.018)				
PAT*VAL					0.024***	0.029***	0.007**	0.010***
					(0.009)	(0.010)	(0.003)	(0.003)
R&D	-0.273***	-0.249***	0.027	0.039	-0.194***	-0.189***	0.021	0.050**
	(0.096)	(0.093)	(0.021)	(0.026)	(0.055)	(0.058)	(0.016)	(0.020)
SIZE	0.015***	0.016***	0.002*	0.001	0.012***	0.014***	0.002**	0.001
	(0.005)	(0.004)	(0.001)	(0.001)	(0.003)	(0.003)	(0.001)	(0.001)
EXPR	-0.003	-0.002	-0.001	-0.001*	-0.001	-0.001	-0.001	-0.001
	(0.002)	(0.002)	(0.000)	(0.001)	(0.002)	(0.002)	(0.000)	(0.001)
EDUC	-0.036	-0.051	0.001	0.001	-0.035	-0.049*	0.001	0.002
	(0.034)	(0.033)	(0.007)	(0.009)	(0.026)	(0.027)	(0.007)	(0.009)
CORP	0.097	0.109	0.115***	0.124***	0.076	0.093	0.116***	0.120***
	(0.102)	(0.099)	(0.022)	(0.027)	(0.076)	(0.080)	(0.021)	(0.028)
INNO	0.092**	0.084**	-0.004	-0.011	0.068**	0.066**	-0.002	-0.014
	(0.043)	(0.041)	(0.009)	(0.011)	(0.028)	(0.030)	(0.008)	(0.010)
CAPA	0.001	0.001	0.000	0.000	0.001	0.001	0.000	0.000
	(0.001)	(0.001)	(0.000)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)
Constant	0.044	0.117*	0.022	0.052***	0.051	0.120**	0.02	0.052***
	(0.070)	(0.068)	(0.015)	(0.019)	(0.052)	(0.055)	(0.015)	(0.019)
Observations	2800				2800			

Notes: The table presents the coefficients from 3SLS regressions. The unweighted patent count PAT is instrumented by the 2-digit industry average unweighted patent count, the value-weighted patent count PAT*VAL is instrumented by the 2-digit industry average value-weighted and unweighted patent count. The numbers of employees working in R&D are instrumented by the 2-digit industry averages. In the 3SLS regressions, the estimations for the different financial measures are jointly estimated for PAT and for PAT*VAL, respectively. All standard errors are adjusted for heteroscedasticity. ***, **, * denote that the coefficient is significantly different from zero at a 0.01, 0.05 and 0.10 level.

C Appendix to Chapter 3

Table C.1: Definition of variables

Variable	Definition and Source
Parent-level	
y_{ict}	Binary location variable that equals 1 if parent i holds an affiliate in host country c in year t and zero else. Source: MiDi
Productivity	Logarithm of the ratio of sales over employees. Source: MiDi
Parent-sector-level	
R&D	Expenditures for innovation over total sales among German industries. Source: Centre for European Economic Research (ZEW)
PATEFF	Perception-based measure of the effectiveness of patents for protecting product innovation. Source: Cohen et al. (2000)
Affiliate-level	
Log(Sales)	Logarithm of affiliate sales. Source: MiDi
Log(FDI)	Stock of direct investment (IMF/OECD method, see Lipponer (2006) for details). Source: MiDi
Log(Employees)	Logarithm of total number of an affiliate's employees. Source: MiDi
Ownership share	Share of affiliate's equity held by German parent. Source: MiDi
Fixed/Total Assets	Fixed over total assets. Source: MiDi
Profitability	Profit over total assets. Source: MiDi
Country-level	
PAT	Index of patent protection that covers the five categories extent of coverage, membership in international patent agreements, duration of protection, enforcement mechanisms and provisions for loss of patent protection. The categories are scored with values ranging from 0-1 and an unweighted sum (0-5) is constructed. Source: Park (2008); Ginarte and Park (1997)
PERC-IPR	Perception-based index of intellectual property right protection, 1-7 (best). Source: World Economic Forum
Corporate Tax	Statutory corporate tax rate. Sources: Various issues of corporate tax guides of PriceWaterhouseCoopers, KPMG, Coopers&Lybrand, Ernst&Young and information from the International Bureau of Fiscal Documentation (IBFD)
Schooling	Share of pupils that progress to secondary school. Source: World Bank Development Indicator
Log(GDPpc)	Logarithm of GDP per capita. Source: World Bank Development Indicator
Exports	Exports of goods and services as a share of GDP. Source: World Bank Development Indicator
Rule of Law	Rule of Law (property rights, freedom from corruption). Source: Heritage Foundation
Trade Openness	Open Markets (trade freedom, investment freedom, financial freedom). Source: Heritage Foundation

Table C.2: Patent protection across countries

Country	Mean	SD	Country	Mean	SD	Country	Mean	SD
Algeria	2.96	0.19	Guyana	1.41	0.33	Pakistan	1.99	0.54
Argentina	3.56	0.72	Honduras	2.58	0.59	Panama	2.91	1.26
Australia	4.17	0.00	Hong Kong	3.51	0.53	Paraguay	2.27	0.69
Austria	4.29	0.07	Hungary	4.19	0.27	Peru	3.12	0.34
Bangladesh	1.87	0.00	India	2.42	1.27	Philippines	3.57	0.88
Belgium	4.63	0.08	Indonesia	2.27	0.63	Poland	3.86	0.38
Bolivia	3.08	0.61	Iran	1.91	0.00	Portugal	4.03	0.52
Brazil	2.89	1.22	Ireland	4.49	0.31	Romania	3.80	0.33
Bulgaria	4.06	0.72	Israel	3.80	0.57	Russian Federation	3.61	0.12
Cameroon	2.46	0.52	Italy	4.56	0.20	Saudi Arabia	2.21	0.66
Canada	4.56	0.19	Jamaica	3.09	0.25	Senegal	2.34	0.52
Chile	4.16	0.21	Japan	4.59	0.14	Slovak Republic	3.38	0.72
China	3.10	0.98	Jordan	2.51	1.26	Spain	4.29	0.07
Columbia	3.35	0.53	Kenya	2.84	0.40	Sweden	4.50	0.07
Congo	2.40	0.60	South Korea	4.12	0.22	Switzerland	4.29	0.07
Costa	2.45	0.77	Lithuania	3.39	0.66	Tanzania	2.53	0.18
Cyprus	3.25	0.40	Luxembourg	4.06	0.14	Thailand	2.53	0.13
Czech Republic	3.50	0.73	Malaysia	3.07	0.39	Trinidad and Tobago	3.24	0.79
Democratic Congo	1.86	0.33	Malta	2.75	1.01	Tunisia	2.41	0.80
Denmark	4.63	0.08	Marocco	2.79	0.90	Turkey	3.56	0.79
Egypt	2.12	0.57	Mauritius	2.14	0.37	USA	4.88	0.00
El Salvator	3.36	0.13	Mexico	3.57	0.38	Uganda	2.94	0.08
Ethiopia	1.38	1.19	Mozambique	1.26	1.17	Ukraine	3.68	0.00
Finland	4.54	0.13	Nepal	1.92	0.23	United Kingdom	4.54	0.00
France	4.63	0.08	Netherlands	4.63	0.08	Uruguay	2.91	0.73
Ghana	3.11	0.26	New Zealand	4.01	0.00	Venezuela	3.15	0.29
Greece	3.91	0.42	Nigeria	2.97	0.18	Vietnam	2.94	0.08
Guatemala	1.84	1.14	Norway	4.14	0.15	Zambia	1.77	0.16
Overall mean			3.24					
Overall standard deviation			1.03					
Between standard deviation			0.93					
Within standard deviation			0.46					

Notes: The Table presents the country means for the time-varying Ginarte-Park index of patent protection.

Table C.3: Industry characteristics

NACE 1 Code	Industry	R&D	PATEFF
1500	Manufacture of food products, beverages	1.40	18.26
1600	Manufacture of tobacco products	1.37	-
1700	Manufacture of textiles	1.94	20.00
1800	Manufacture of textile products	1.95	-
1900	Manufacture of leather, leather products	1.92	-
2000	Manufacture of wood, wood products	3.16	-
2100	Manufacture of pulp, paper, paper products	3.13	36.94
2200	Publishing, printing, reproduction of recorded media	3.16	12.08
2300	Manufacture of coke, refined petroleum products and nuclear fuel	4.64	33.33
2400	Manufacture of chemicals, chemical products	4.44	37.46
2440	Manufacture of pharmaceutical products	4.20	50.20
2500	Manufacture of rubber, plastic products	3.65	32.71
2600	Manufacture of other non-metallic mineral products	2.92	21.11
2700	Manufacture of basic metals	2.74	20.00
2800	Manufacture of metal products	2.74	39.43
2900	Manufacture of machinery, equipment n.e.c.	4.80	42.94
3000	Manufacture of office machinery, computers	6.90	41.00
3100	Manufacture of electrical machinery, apparatus	6.85	34.55
3200	Manufacture of radio, television, communication equipment and apparatus	7.21	25.82
3300	Manufacture of medical, precision, optical instruments, watches and clocks	8.23	40.43
3400	Manufacture of motor vehicles, trailers, semi-trailers	6.84	43.09
3500	Manufacture of other transport equipment	6.07	-
3510	Building, repairing of ships, boats	7.94	-
3520	Manufacture of railed vehicles	7.94	-
3530	Manufacture of aircraft, spacecraft	7.94	32.92
3540	Manufacture of motorcycles, bicycles, invalid	7.94	-
3550	Manufacture of other transport equipment	7.94	-
3600	Manufacture of furniture, Manufactureacturing	2.60	33.81
3700	Recycling	2.62	-
4000	Electricity, gas, steam, hot water supply	0.60	-
Industry average		4.41	32.43
Industry standard deviation		2.40	9.93

Notes: The Table presents the values for the time-constant measure of patent effectiveness (PATEFF) and the mean values for the time-varying measures of R&D intensity (R&D). All definitions of the variable are summarized in Table C.1.

Table C.4: Entry decision (with country-year FE)

Dependent variable: Location		
	(1)	(2)
Productivity	0.0109***	0.0105***
	(0.0014)	(0.0013)
PAT*PATEFF	0.0005***	
	(0.0001)	
PAT*R&D		0.0020***
		(0.0004)
R&D		-0.0078***
		(0.0018)
Observations	261434	275373
Indiv. Parents	2490	2630
Destinations	84	84
Adjusted R^2	0.1958	0.1943

Notes: Standard errors are clustered by parent firm, with ***, **, * denoting significance at 1%, 5% and 10% levels respectively. The dependent variable is the binary location variable y_{ict} that equals 1 if parent i holds an affiliate in host country c in year t. All specifications include country-year, year and parent fixed effects.

Table C.5: Size (with country-year FE)

Dependent variable:	Log(FDI)		Log(Sales)		Log(Employees)	
	(1)	(2)	(3)	(4)	(5)	(6)
Productivity	0.1114***	0.1128***	-0.4260***	-0.4408***	-0.5684***	-0.5768***
	(0.0263)	(0.0256)	(0.0579)	(0.0563)	(0.0309)	(0.0297)
PAT*PATEFF	0.0032**		0.0022		0.0013	
	(0.0015)		(0.0026)		(0.0016)	
R&D		-0.0508		-0.1724		-0.0493
		(0.0920)		(0.1163)		(0.0857)
PAT*R&D		0.0075		0.0282		0.0085
		(0.0207)		(0.0261)		(0.0195)
Observations	10002	10544	10332	10906	10332	10906
Indiv. Parents	2344	2472	2394	2526	2394	2526
Destinations	72	73	72	73	72	73
Adjusted R^2	0.4243	0.4208	0.5040	0.4970	0.6646	0.6650

Notes: Standard errors are clustered by parent firm, with ***, **, * denoting significance at 1%, 5% and 10% levels respectively. All specifications include country-year, year and parent fixed effects. Additionally, dummies for an affiliate's age and sector are included.

Table C.6: Ownership (with country-year FE)

Dependent variable: Ownership Share		
	(1)	(2)
Productivity	-0.0027	-0.0018
	(0.0033)	(0.0031)
Log(Sales)	0.0030	0.0024
	(0.0030)	(0.0029)
Profitability	-0.0253	-0.0313*
	(0.0180)	(0.0166)
Fix/Total Assets	-0.0157	-0.0153
	(0.0161)	(0.0155)
PAT*PATEFF	-0.0002	
	(0.0002)	
R&D		0.0112
		(0.0110)
PAT*R&D		-0.0018
		(0.0024)
Observations	10330	10904
Indiv. Parents	2393	2525
Destinations	72	73
Adjusted R^2	0.3178	0.3207

Notes: Standard errors are clustered by parent firm, with ***, **, * denoting significance at 1%, 5% and 10% levels respectively. All specifications include country-year, year and parent fixed effects. Additionally, dummies for an affiliate's age and sector are included.

Table C.7: Sensitivity check with dependency on secrecy

Dependent variable:	Location (1)	Log(Sales) (2)	Log(Employees) (3)	Log(FDI) (4)	Ownership (5)
Productivity	0.0110***	0.1856**	-0.1446***	0.0031	0.0052*
	(0.0014)	(0.0803)	(0.0437)	(0.0332)	(0.0031)
Log(GDPpc)	0.0234***	0.9708***	0.5286***	0.6568***	-0.0153
	(0.0024)	(0.3002)	(0.1966)	(0.1158)	(0.0134)
Corporate Tax	-0.0003**	0.0035	0.0052	-0.0066	-0.0013*
	(0.0001)	(0.0121)	(0.0078)	(0.0049)	(0.0007)
Schooling	0.0004***	-0.0001	-0.0010	0.0003	-0.0004*
	(0.0001)	(0.0054)	(0.0030)	(0.0027)	(0.0002)
Exports	0.0005***	0.0232**	0.0171**	0.0054	-0.0003
	(0.0001)	(0.0104)	(0.0071)	(0.0040)	(0.0005)
Rule of Law	-0.0001	-0.0131	-0.0061	-0.0066**	-0.0003
	(0.0000)	(0.0080)	(0.0042)	(0.0031)	(0.0004)
Trade Openess	0.0003***	0.0330***	0.0169**	0.0082**	0.0017***
	(0.0001)	(0.0111)	(0.0068)	(0.0037)	(0.0005)
PAT	0.0171***	-0.0879	-0.3374	-0.0186	-0.0031
	(0.0048)	(0.3232)	(0.2389)	(0.1467)	(0.0208)
PAT*Secrecy	-0.0001	0.0072	0.0054	0.0003	0.0006*
	(0.0001)	(0.0068)	(0.0049)	(0.0028)	(0.0004)
Affiliate Age	no	yes	yes	yes	yes
Affiliate Controls	no	no	no	no	yes
Observations	261434	11208	11208	10818	11208
Indiv. Parents	2490	2399	2399	2351	2399
Destinations	84	73	73	73	73
Adjusted R^2	0.1939	0.6105	0.6211	0.4236	0.3092

Notes: Standard errors are clustered by parent firm, with ***, **, * denoting significance at 1%, 5% and 10% levels respectively. All specifications include country, year and parent fixed effects. The specifications in Columns 2-5 additionally include dummies for an affiliate sector.

Table C.8: Entry decision with perception-based IPR index

Dependent variable: Location decision			
	(1)	(2)	(3)
Productivity	0.0047***	0.0049***	0.0049***
	(0.0005)	(0.0006)	(0.0005)
Log(GDPpc)	0.0109***	0.0116***	0.0106***
	(0.0021)	(0.0021)	(0.0021)
Corporate Tax	-0.0002***	-0.0003***	-0.0003***
	(0.0001)	(0.0001)	(0.0001)
Schooling	0.0001*	0.0001**	0.0001**
	(0.0000)	(0.0000)	(0.0000)
Exports	0.0000	0.0000	0.0000
	(0.0000)	(0.0000)	(0.0000)
Rule of Law	-0.0001**	-0.0002***	-0.0002***
	(0.0001)	(0.0001)	(0.0001)
Trade Openness	-0.0000	-0.0000	-0.0000
	(0.0000)	(0.0000)	(0.0000)
PERC-IPR	0.0032***	-0.0102***	-0.0034**
	(0.0007)	(0.0027)	(0.0016)
PERC-IPR*PATEFF		0.0004***	
		(0.0001)	
PERC-IPR*R&D			0.0014***
			(0.0003)
R&D			-0.0052***
			(0.0012)
Observations	657031	601315	631966
Indiv. Parents	2226	2026	2140
Destinations	98	98	98
Adjusted R^2	0.1742	0.1815	0.1774

Notes: Standard errors are clustered by parent firm, with ***, **, * denoting significance at 1%, 5% and 10% levels respectively. The dependent variable is the binary location variable y_{ict} that equals 1 if parent i holds an affiliate in host country c in year t. All specifications include country, year and parent fixed effects. The sample covers the years 2006-2010.

Table C.9: Size of foreign affiliates with perception-based IPR index

Dependent variable:	Log(FDI)			Log(Employees)			Log(Sales)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Productivity	0.0066	0.0228	0.0144	0.2468***	0.2398***	0.2227***	-0.0770***	-0.0691**	-0.0719***
	(0.0137)	(0.0139)	(0.0137)	(0.0519)	(0.0572)	(0.0550)	(0.0263)	(0.0281)	(0.0274)
Log(GDPpc)	0.3219***	0.2978***	0.2904***	0.3454	0.4175*	0.4291*	0.1968	0.1824	0.2130*
	(0.0865)	(0.0872)	(0.0863)	(0.2409)	(0.2449)	(0.2454)	(0.1217)	(0.1193)	(0.1213)
Corporate Tax	-0.0144***	-0.0138***	-0.0148***	-0.0124	-0.0113	-0.0099	-0.0033	-0.0020	-0.0033
	(0.0044)	(0.0045)	(0.0044)	(0.0114)	(0.0112)	(0.0114)	(0.0061)	(0.0058)	(0.0060)
Schooling	0.0012	-0.0005	-0.0005	-0.0082	-0.0068	-0.0106	-0.0084*	-0.0052	-0.0104**
	(0.0031)	(0.0032)	(0.0031)	(0.0084)	(0.0087)	(0.0085)	(0.0048)	(0.0044)	(0.0048)
Exports	0.0045*	0.0042	0.0037	-0.0034	-0.0030	-0.0009	0.0029	0.0034	0.0036
	(0.0025)	(0.0026)	(0.0025)	(0.0060)	(0.0061)	(0.0060)	(0.0036)	(0.0036)	(0.0035)
Rule of Law	-0.0048*	-0.0045	-0.0045	-0.0068	-0.0068	-0.0069	0.0006	0.0007	0.0011
	(0.0027)	(0.0028)	(0.0028)	(0.0060)	(0.0061)	(0.0062)	(0.0033)	(0.0034)	(0.0034)
Trade Openness	0.0010	0.0019	0.0017	0.0115*	0.0135**	0.0124**	0.0073**	0.0080***	0.0078***
	(0.0018)	(0.0019)	(0.0019)	(0.0062)	(0.0065)	(0.0062)	(0.0029)	(0.0029)	(0.0029)
PERC-IPR	0.0760**	0.1205	0.1081**	0.1273	0.3355	0.1662	-0.0125	0.0671	0.0490
	(0.0303)	(0.0802)	(0.0484)	(0.0793)	(0.2113)	(0.1251)	(0.0480)	(0.1477)	(0.0780)
PERC-IPR*PATEFF		-0.0015			-0.0059			-0.0018	
		(0.0020)			(0.0049)			(0.0036)	
PERC-IPR*R&D			-0.0064			-0.0091			-0.0119
			(0.0062)			(0.0154)			(0.0094)
R&D			0.0271			0.0668			0.0675
			(0.0295)			(0.0747)			(0.0458)
Observations	23851	22125	23077	24832	22981	23973	24832	22981	23973
Indiv. Parents	2147	1954	2067	2177	1981	2093	2177	1981	2093
Destinations	84	82	84	84	82	84	84	82	84
Adjusted R^2	0.4781	0.4806	0.4813	0.6347	0.6499	0.6429	0.663	0.6754	0.6688

Notes: Standard errors are clustered by parent firm, with ***, **, * denoting significance at 1%, 5% and 10% levels respectively. All specifications include country, year and parent fixed effects. Additionally, dummies for an affiliate's age and sector are included. The sample covers the years 2006-2010.

Table C.10: Ownership share of foreign affiliates with perception-based IPR index

Dependent variable: Ownership Share			
	(1)	(2)	(3)
Productivity	-0.0005	-0.0004	-0.0012
	(0.0027)	(0.0030)	(0.0028)
Log(GDPpc)	-0.0049	-0.0023	-0.0067
	(0.0139)	(0.0132)	(0.0136)
Corporate Tax	-0.0013**	-0.0013**	-0.0014**
	(0.0006)	(0.0006)	(0.0006)
School System	-0.0002	-0.0003	-0.0002
	(0.0004)	(0.0004)	(0.0004)
Exports	-0.0003	-0.0001	-0.0003
	(0.0003)	(0.0003)	(0.0003)
Rule of Law	-0.0012***	-0.0011***	-0.0011***
	(0.0004)	(0.0004)	(0.0004)
Trade Openness	0.0001	0.0002	0.0002
	(0.0003)	(0.0003)	(0.0003)
PERC-IPR	0.0028	0.0207	0.0167**
	(0.0047)	(0.0142)	(0.0071)
PERC-IPR*PATEFF		-0.0005	
		(0.0003)	
PERC-IPR*R&D			-0.0026***
			(0.0009)
R&D			0.0131***
			(0.0046)
Observations	24816	22965	23957
Indiv. Parents	2177	1981	2093
Destinations	84	82	84
Adjusted R^2	0.4738	0.4670	0.4739

Notes: Standard errors are clustered by parent firm, with ***, **, * denoting significance at 1%, 5% and 10% levels respectively. All specifications include country, year and parent fixed effects. Additionally, dummies for an affiliate's age and sector are included. The sample covers the years 2006-2010.

Table C.11: Location decision with conditional logit estimation

Dependent variable: Location						
	Without Country FE			With Country FE		
	(1)	(2)	(3)	(4)	(5)	(6)
Log(GDPpc)	0.4309***	0.4502***	0.4465***	0.6953***	0.6567***	0.7085***
	(0.0250)	(0.0263)	(0.0254)	(0.0973)	(0.1029)	(0.0983)
Corporate Tax	0.0210***	0.0227***	0.0216***	-0.0215***	-0.0228***	-0.0204***
	(0.0021)	(0.0023)	(0.0022)	(0.0040)	(0.0043)	(0.0041)
Schooling	-0.0131***	-0.0137***	-0.0135***	0.0036**	0.0032*	0.0030
	(0.0009)	(0.0009)	(0.0009)	(0.0018)	(0.0018)	(0.0018)
Exports	-0.0095***	-0.0103***	-0.0099***	0.0059*	0.0056	0.0078**
	(0.0007)	(0.0008)	(0.0008)	(0.0032)	(0.0035)	(0.0033)
Rule of Law	-0.0065***	-0.0066***	-0.0069***	0.0002	0.0004	-0.0005
	(0.0011)	(0.0011)	(0.0011)	(0.0024)	(0.0025)	(0.0024)
Trade Openess	-0.0191***	-0.0224***	-0.0204***	0.0145***	0.0137***	0.0148***
	(0.0019)	(0.0019)	(0.0020)	(0.0028)	(0.0030)	(0.0029)
PAT	1.6568***	1.5752***	1.5321***	0.2178***	0.0849	0.1090
	(0.0545)	(0.0867)	(0.0836)	(0.0544)	(0.0937)	(0.0903)
Productivity	0.2567***	0.2763***	0.2678***	0.2880***	0.3100***	0.2999***
	(0.0297)	(0.0323)	(0.0298)	(0.0302)	(0.0328)	(0.0304)
PAT*PATEFF		0.0035*			0.0045**	
		(0.0021)			(0.0020)	
PAT*R&D			0.0332**			0.0230
			(0.0160)			(0.0169)
Observations	278448	256334	269870	278448	256334	269870
Indiv. Parents	2623	2400	2533	2623	2400	2533
Pseudo R^2	0.1743	0.1794	0.1779	0.3099	0.3167	0.3126

Notes: Standard errors are clustered by parent firm, with ***, **, * denoting significance at 1%, 5% and 10% levels respectively. The dependent variable is the binary location variable y_{ict} that equals 1 if parent i holds an affiliate in host country c in year t. All specifications include year and parent fixed effects, specifications in columns 5-8 include additional country fixed effects.

List of Figures

1.1 Locally weighted regressions 32

2.1 Importance of patents 58

3.1 Scatter plots of the dependent variables 83

List of Tables

1.1 Identifying access to loans 13
1.2 Coding of the dependent variables 14
1.3 Distribution of *perceived access* among financial categories 15
1.4 Firm-level explanatory variables 21
1.5 Country-level explanatory variables 23
1.6 Heterogeneity of firms with and without demand for loans 25
1.7 Access to credit 27
1.8 Usage of credit 30
1.9 Perceived access to finance 33

2.1 Patenting across sectors 48
2.2 Coding of the dependent variables 50
2.3 Descriptive statistics 51
2.4 Patenting firms versus non-patenting firms 52
2.5 Financial functions of patents 59
2.6 Bank finance 63
2.7 Venture capital finance 65

3.1 Sample characteristics 81
3.2 Descriptive statistics 82
3.3 Location decision 85
3.4 Location decision with heterogeneity in initial host country characteristics 87
3.5 Size of foreign affiliates 89
3.6 Ownership share of foreign affiliates 90

List of Tables

A.1 Definition of variables 98
A.2 Alternative exclusion restrictions 99
A.3 Heckman two-step estimator 100
A.4 Standard errors clustered on industry-country-level 101
B.1 Industry classifications within industry groups 102
B.2 Definition of variables 103
B.3 Functions of patents (ordered probit) 104
B.4 Functions of patents (bivariate ordered probit) 105
B.5 3SLS regressions 106
C.1 Definition of variables 107
C.2 Patent protection across countries 108
C.3 Industry characteristics 109
C.4 Entry decision (with country-year FE) 110
C.5 Size (with country-year FE) 111
C.6 Ownership (with country-year FE) 112
C.7 Sensitivity check with dependency on secrecy 113
C.8 Entry decision with perception-based IPR index 114
C.9 Size of foreign affiliates with perception-based IPR index 115
C.10 Ownership share of foreign affiliates with perception-based IPR index . . 116
C.11 Location decision with conditional logit estimation 117

Bibliography

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