Master programme in Economic Growth, Innovation and Spatial Dynamics

The Economic Effect of Jena University on the Regional Economy – Knowledge Transfer and Knowledge Capital Reassessed

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Abstract: Universities are essential components for regional economic growth; through their research, teaching and entrepreneurial activities, they contribute to the regional economy in terms of knowledge, human capital and firm formation. This thesis not just accounts for and quantifies the overall economic effect of Jena University on the regional economy, but also reveals and illustrates exemplarily how the effect emerges on the micro-level. Therefore, patent networks and joint patents act as a proxy for the economic impact. First, the macro-economic effect of Jena University´s research and teaching activities is quantified by estimating a knowledge capital stock. Second, based on a patent data analysis covering patenting activity since 1999, knowledge transfer from the university to the regional economy is analyzed.

The findings suggest that Jena University has an economic impact on the regional economy in terms of knowledge creation and transfer, but also in terms of the effects from human and research capital generated at the university. When quantifying the economic effect of Jena University on the regional economy, it is argued that an effect of 459.9 mil Euro in terms of knowledge capital is operative in the region in 2013, which corresponds to 1.2 percent of Jena region´s domestic product. This economic impact is reflected in Jena University´s predominately regional cooperation and research partners, its technological focus that reflects the regional clusters and its role as promoter of entrepreneurship.

Key words: university, regional economics, academic patenting, knowledge capital, knowledge transfer

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1. Introduction

The economic effect of universities on the surrounding regional economy has been object to a magnitude of research (e.g. Jaffe, 1989; Acs et al. 1992, 2002; Feldman, 1994; Anselin et al. 1997; Blind & Grupp, 1999; Autant-Bernard, 2001; Fritsch et al. 2008; Brenner & Schlump, 2013). One of the main findings is that universities affect and influence the surrounding regional economy through direct and indirect ties in terms of knowledge, human capital and firm formation. However, the intensity of this effect is influenced by various components such as the region´s ability to absorb knowledge and the regional economic infrastructure (Brenner & Schlump, 2013).

The theoretical background of this thesis and its empirical findings is provided by the endogenous growth theory (Romer, 1986; Lucas, 1988). This theory explains economic growth based on innovation as a combination of labor and knowledge – i.e. R&D – on the one hand; and as a combination of human capital and knowledge – e.g. importance of knowledge production in universities – on the other hand. However, knowledge cannot always be produced effectively as codified knowledge that is expressed in language, symbols or any other form of representation (Gertler, 2003). For that reason, tacit knowledge is perceived as the prevalent cause in explaining a region´s economic success, as it can hardly be transmitted over huge distances (e.g. Griliches, 1979; Audretsch et al. 2010).

Past research on the economic impact of universities on the surrounding region and its firms points out that the economic effect and the knowledge produced at universities, mainly affect the surrounding region (Niebuhr, 2000; Peri, 2005; Fritsch & Slavtchev, 2007; Andersson et al. 2009; Belenzon & Schrankerman, 2010). Universities contribute to the regional economy through their research, teaching and entrepreneurial activities, thereby increasing the region´s knowledge and human capital endowment as well as fostering new business formation. However, the regional economy has to be able to absorb these factors generated at universities, and therefore establish effective linkages and conduits between universities and firms nearby (Geuna & Muscio, 2009). This is due to the fact that the relationship between a university and its surrounding is not a mono-directional; the regional economy also influences the university´s direction (Brenner & Schlump, 2013).

1.1. Objective of the Study

The purpose of this thesis is to analyze and quantify the economic effect of Jena University´s teaching and research activities on the regional economy. This is done by a two-step approach bringing together macro- and micro-economic perspective: First, it is attempted to quantify the macro-economic effect of Jena University´s research and teaching activities. How can the economic effect be quantified and does Jena region benefit from the human and research capital generated at Jena University? Then, it is focused on a micro-economic perspective to reveal how this contribution to the regional economy shows up in the real (micro) world. This is exemplarily done by analyzing how knowledge is transferred from Jena University to the regional economy and its firms. Thereby, patent cooperation will be examined with the objective to assess patterns, intensity and the technological focus of patents emerging through research cooperation. What patterns can be revealed in joint patent applications of Jena University and regional actors? What are the technological fields of cooperation and does this reflect the region´s technological endowment? Does Jena University foster entrepreneurship and support its spin-offs?

This thesis combines macro- and micro-economic perspective in order to give a comprehensive analysis of the economic effect of Jena University on the regional economy. The aim is not just to account for and quantify the overall economic effect, but also to reveal and illustrate exemplarily how the effect emerges on the micro-level. Therefore, patent networks and joint patents act as proxy for the economic impact of Jena University. These networks represent conduits for knowledge capital that is generated at Jena University.

It is argued that Jena University has an economic impact on the regional economy in terms of knowledge creation and transfer, but also in terms of the effects from human and research capital flows generated at Jena University. When quantifying the economic effect of Jena University, it is argued that a regional effect of 459.9 mil Euro in terms of knowledge capital flows is operative in the Jena region in 2013, which corresponds to 1.2 percent of Jena region´s domestic product. This economic impact is reflected on the micro-level in Jena University´s predominately regional cooperation and research partners, its technological focus that reflects the regional clusters and its role as promoter of entrepreneurship.

1.2. Method and Sample

This thesis is based on two methodological approaches. First, a production function approach will be used to estimate the macro-economic impact of Jena University. Thereby, the knowledge capital stock generated at Jena University and its regional economic effect in terms of human and research capital flows will be calculated (Taurus, 2007; Giesecke & Madden, 2006; Pfähler et al. 1999; Guellec et al. 2001; Del Barrio-Castro & Garcia-Quevedo, 2005). Second, in order to analyse and outline the micro-economic contribution of Jena University, the patterns of knowledge transfer and cooperation will be examined. On that account, a patent data analysis with data from "EPO Worldwide Patent Statistical Database" PATSTAT, OECD database REGPAT and the publication database SCOPUS will be applied. To capture all university-based patents, an approach by Fraunhofer Institute for Systems and Innovation Research (Dornbusch et al. 2012) to identify not only university-owned, but also university-invented patents will be made use of. In this thesis, Jena region is defined as the area in an about 50 kilometer-radius around the city of Jena. For a complete list of the included NUTS3-regions, see Appendix A.

1.3. Outline of the Thesis

The remainder of the thesis is organized as follows: Section 2 summarizes and discusses the relevant literature on the economic regional effect of universities. It also introduces Jena University and its surrounding regional economy. Section 3 presents the estimation of the knowledge capital stock including the applied data and methodology. Section 4 outlines and discusses the macro-economic effect of Jena University and bridges the gap to the micro-economic analysis. Section 5 presents the patent data analysis including the applied data and methodology. Section 6 examines the patenting activities of Jena University and discusses these in respect to the examined literature. The last section ends with a summary of the quintessential arguments and some concluding remarks.

1.4. Supporting Information

The idea for this thesis emerged from an internship at DIW Econ Berlin during spring 2016. By courtesy of DIW Econ Berlin data on Jena University for the analysis was provided. Moreover, they provided access to the patent databases. A complete set of the applied data and results can be provided on request.

2. Theory and Context

2.1. Knowledge and the Regional Economy

The creation and transfer of knowledge – as a prerequisite for innovation – is seen as a fundamental driver for economic growth. That is why in the past decades the interest in studying the role of human capital and knowledge increased significantly. Especially with the rise of the endogenous growth theory, when technological change has been treated as an endogenous factor, knowledge creation and transfer received wide attention in academia and policy making (Lucas, 1988; Romer, 1986). Universities and public research institutions play an essential role in the process of creation and transfer of knowledge (Jaffe, 1989; Acs et al. 1992, 2002; Feldman, 1994; Anselin et al. 1997; Graf & Henning, 2006; D´Éste & Iammarino, 2010). Universities create human capital and knowledge that can "spill over" and be transferred to the regional economy in many different ways – by cooperation, research, alumni, internships or employee mobility and can be exchanged in formal and informal relations. In return, firms use this knowledge to create new innovations and thus promote regional competitiveness (Anselin et al. 1997; Acs et al. 2002; Fritsch & Slavtchev, 2007). That is why universities are a driving force in promoting innovative activities and regional economic growth. Moreover, Edquist (2006) emphasizes the importance and the essential contribution of universities to the regional innovation system.

2.2. Tasks of Universities

Traditionally, the university´s impact on a region was due to its main activities: research and training. Lately, however, the promotion of entrepreneurship and supporting spin-offs has become another important activity of universities (Guerro et al. 2015). **Teaching** and training was and still is the universal task and raison d'être of a university (Kirbey et al. 2011). Universities train young people, convey knowledge, skills and competences, and contribute to the production of human capital (Lucas, 1988). For that reason, universities contribute to the regional economy through the creation, attraction and upkeep of skilled human capital and entrepreneurs (Bramwell & Wolfe, 2008). **Research** is another essential and legitimate activity of universities, especially in the age of a learning and knowledge-based economy. While the main aim of research is the production, transfer and commercialization of knowledge (Romer, 1986; Solow, 1956), the output are publications, patents or licenses. Besides the two traditional university activities, the promotion of **Entrepreneurship** is an increasingly important duty of a university. Universities support students with entrepreneurship training, incubation activities or provide money or venture capital. Main focus here is the creation of new firms, spin-offs and the economic exploitation of knowledge generated in research. By doing so, universities act as promoters of networks and cooperation while reacting to regional needs and demand (Porter, 2007). For that reason, entrepreneurship can be found in all levels of a university: management, researchers, alumni and students that potentially will found a firm. By conducting knowledge spillovers, entrepreneurship is recognized as a driver for economic growth, increasing competition and contributing to economic diversity (Audretsch & Keilbach, 2004). That is why it is argued that these impacts generate various externalities in terms of demography, infrastructure, culture and education that will later be mirrored in the region´s competitiveness, productivity, networks and innovation patterns (Powers & McDouglas, 2005; Porter, 2007).

2.3. Regional Effect of Universities

There exists a large body of literature that is devoted to the analysis of universities – academic research and training in particular – and their effect on the regional economy – innovation activity and economic growth in particular. A majority of the literature on the effect of universities studies the US, but there are also some European studies (e.g. Jaffe, 1989; Acs et al. 1992, 2002; Feldman, 1994; Anselin et al. 1997; Blind & Grupp, 1999; Autant-Bernard, 2001; Fritsch et al. 2008; Brenner & Schlump, 2013). One of the main finding is that knowledge generated at a university mainly affects the surrounding region (Niebuhr, 2000; Peri, 2005; Fritsch & Slavtchev, 2007; Andersson et al. 2009; Belenzon & Schrankerman, 2010). From an economic point of view, this phenomenon is caused by the low costs for transaction and acquisition of knowledge in close proximity to a university (Blume & Fromm, 2000). Knowledge spillover and knowledge flows are created and fostered by various mechanisms such as cooperation, graduates, movement of employees and informal relationships between employees (Fritsch et al. 2008). Furthermore, most universities and research institutes provide consultancy and support for new businesses; therefore, universities are also an essential source for spin-offs (Guena & Muscio, 2009).

Graduates, or generally the human capital that is generated at a university is essential for a region and its firms. According to Brenner and Schlump (2013) a highly-skilled labor force is fundamental for a firm´s ability to innovate and be competitive. This is due to that employees in R&D and other highly-qualified employees develop new products and processes (Czanitzki

& Hottenrott, 2009). Especially university graduates bring new and up-to-date knowledge into firms, which enables and fosters these innovation mechanisms. Moreover, a qualified labor force increases a firm´s ability to absorb and process new knowledge (Brenner & Schlump, 2013). A region´s labor pool is often specialized by which regional firms are supplied with. This is due to a strong connection between the research conducted at a university and the regional labor market (Fritsch et al. 2008; Fritsch & Slavtech, 2007). For Germany, a study conducted by ifo Institute showed that roughly 40 percent of graduates from university are likely to have left the region of education five years after graduation (Haussen & Übelmesser, 2015). Yet, for the state of Thuringia, where Jena University is located, the study attests a comparably high share of roughly two thirds of graduates that have left the region five years after graduation. This illustrates that the simple presence of a university does not imply a huge number of highly-qualified graduates and employees staying in the region. Fritsch et al. (2008) argue, a regional economy only benefits from graduates if there are suitable jobs for the university graduates at the regional firms.

Cowan and Zinoveya (2013) reason the fact that a university´s effect on the regional industry is localized, descends from the nature of knowledge. While most of the generated knowledge at universities is codified knowledge such as publications and patents, tacit knowledge is essential for the dispersal process (Cowan & Zinoveya, 2013). One advantage of codified knowledge is that it can be spread very widely and with the development of new communication and information technologies also very fast. Tacit knowledge, however, by nature cannot and is strongly localized. In his study on the diffusion of the knowledge incorporated by patents, which is by definition codified knowledge, Jaffe (1993) found evidence that most patents have a strong regional diffusion and access to this knowledge increases geographically over time. By reconceiving this issue, Breschi and Lissoni (2009) emphasized that is it not geographical distance over which knowledge diffusion occurs, but rather social distance. They argue that scientists and inventors learn about a patent and the knowledge it contains through direct social interaction. Consequently, as most social interaction takes place on the local level, one can expect knowledge diffusion that is geographically localized.

In search for quantifying this regional effect or the geographical extend of the university's effect, most studies agree on a declining effect with growing distance from public research or university (Acs et al. 2002; Andersson et al. 2009; Anselin et al. 1997; Fischer & Varga 2003; Fritsch & Slavtechev 2007; Fritsch et al. 2008). Fritsch and Slavtchev (2007) detect with

German patent data that the economic impact of a university becomes operative in a radius of 50 kilometers around the university and elasticity decreases by increasing distance to the university. Anselin et al. (1997) find a significant positive impact of university research in economic activity within a range of 50 miles (approx. 80 kilometers) around the university. Acs et al. (2002) confirm these findings by identifying a range of 80 kilometers around the university to be most affected when studying patents and innovations as measures of the regional production of knowledge. For Sweden, Andersson et al. (2009) arrive at the result that 50 percent of the productivity gains from aggregate university investment are operative within a range of five to eight kilometers surrounding the university.

The economic effect of a university on its surrounding region is not always unquestionable. While in the early 1980s studies done by Dorfman (1983) and Saxenian (1985) emphasize that clusters like Silicon Valley do only exist due to the local universities, later studies by Feldman and Florida (1994) challenge the role of universities as a regional driver for economic growth and innovation. They pointed out that also the regional economic infrastructure contributes a significant share to a region´s economic growth. Besides that, Power and Malmberg (2008) point out that a huge share of the knowledge and findings of research are not used or commercialized in the university´s region. They argue that this is due to three factors: First, academic research and thinking of many scientists is primarily motivated internationally, not regionally. Second, a certain share of research findings is not applicable in the university´s region due to its nature. Third, universities are only able to adjust to the needs of the regional economy to a certain degree.

Summing up, the pure existence of a university does not imply a beneficial economic effect for the surrounding region and its firms. Geuna and Muscio (2009) point out, as universities and researchers vary in how they transmit knowledge, also firms vary in the way they absorb knowledge. In this case, it is important to take into account the degree to which a local university responds to the skills, abilities and knowledge that is needed in the regional economy, but also the region´s ability to absorb the generated knowledge and human capital. Moreover, the relationship between a university and its surrounding economy is not mono-directional. As Brenner and Schlump (2013) emphasize, regional firms or the regional economy as a whole may also have an impact on the university and influence its direction.

2.4. Jena University

Jena University has been founded as Friedrich-Schiller Universität Jena in 1558 and is one of Germany´s oldest universities and rich in tradition. Counting nearly 20,000 students, Jena University makes up roughly 38 percent of all students in Thuringia and is by far the biggest university in the federal state. The university offers 150 undergraduate and graduate studies in 10 different faculties, and is the only full-scale university in Thuringia. It is a member of the Coimbra-Group and considers itself as a European research institute that is committed to excellence in inter- and transdisciplinary research as well as training. Jena University is characterized by various interdisciplinary studies and research projects; for instance, there are five special research fields (Sonderforschungsbereiche) supported by the German Research Funding Organization (Deutsche Forschungsgemeinschaft) and more than 20 graduate colleges and schools. Under the programme of the Academic Excellence Initiative by the German Federal Government, the Jena School of Microbial Communication has been established as one of the university´s lighthouse projects. Three different research areas "Light – Life – Liberty" reflect the university´s research focus and underline the strong interdisciplinary emphasis as well as the university's affiliation with the regional economy. In Figure 1, the cooperating regional research institutes for each research area are illustrated.

Figure 1: Research and Cooperation in the Different Research Areas at Jena University

Source: Jena Universtiy (2016). Author´s illustration.

The research area “Light” connects research in optics and photonics. Extending the research area with the field of innovative materials and energy storage, it is attempted to link biological with medical research. Besides Jena University four research institutes of the Fraunhofer Gesellschaft, the Leibniz Group and a Helmholtz Institute are involved. The research area “Life” unites the research fields of microbiology and biodiversity with a focus in microbial communication, infection research and fundamental research in the therapy of sepsis. Besides Jena University two Leibniz Institutes, a Max-Planck as well as a Helmholtz Institute are part of this merge. While the first two research areas focus on natural science, the third research area “Liberty” is oriented towards humanities. It contains the field of research that deals with the Enlightenment, Idealism, East and Southeast Europe as well as commemorative culture and history; also discussing issues of social change (Jena University, 2014).

2013	students	professors	research fellows	R&D expenditures for universities
Thuringia	52,001	1,127	6,130	335,2 mil €
Jena University	19,664	322	1,233	139,3 mil €
Share of Jena University	37.8%	28.5%	20.1%	41.5%

Table 1: Jena University’s Contribution to Thuringia´s Scientific Landscape in 2013

Source: Jena University (2016), Stifterverband für die Deutsche Wirtschaft (2015). Author´s illustration.

In terms of employing scientific staff, Jena University also plays an important role in the federal state of Thuringia as Table 1 illustrates. 322 professors at Jena University are supported by more than 1,200 research fellows. In other word, Jena University employs about 29 percent of all professors and about 20 percent of all research fellows that work and do research in the federal state. Besides that, about 41.5 percent of all research and development expenditures for universities in Thuringia are allocated to Jena University. Furthermore, Jena University is a research-intensive university. This is also illustrated by the amount of publications generated from the academic staff at the university. The number of publications including papers in peer-reviewed journals and monographies has been doubled from 1,215 in 2000 to about 2,894 publications in 2014 (Scopus, 2016).

The promotion of entrepreneurship and the support for spin-offs is an important part of Jena University´s duties. All activities concerning entrepreneurship are administrated in the “K1 – Gründerservice”, which is the university´s office for entrepreneurship and spin-offs. It is located under the roof of the university’s service centre for research and transfer and funded partly by the federal academic entrepreneurship program EXIST. K1-Gründerservice offers consulting, networking events and activities like workshops and lectures focussing on manifold aspects of starting a business.

2.5. Jena Region

Jena region is characterized by a comparably large number of cluster initiatives and networks. Many firms operate in areas such as micro technology, ophthalmology and biomedicine, architecture and construction. Of international relevance are the industries of optical technologies and photonics, medical technology as well as plastic-, solar- and material science (Impulsregion, 2016). The most important employing firms are the Jena University Clinic with about 5,000 employees, followed by Jena University with about 3,000, Zeiss Jena GmbH accounting for about 2,000 and Jenoptic AG for about 1,700 employees in 2015 (Jenawirtschaft, 2016). In the following, the clusters of optics and medical science shall be assessed in more detail.

Optics is one of the important clusters in the city of Jena, but also in the Jena region. In the state of Thuringia about 15,000 people work in the optical industries, which encompasses more than 170 companies. Most of them are located in the Jena region, which belongs to the most important German clusters in optical and measuring technologies (LEG Thuringia, 2015). Although the Eastern German economy is characterised as a rather compartmentalized one, some internationally considerable companies are located in the area, such as Carl Zeiss AG and Jenoptik. In 2014 about 10 percent of the German turnover in the optical industries was generated in Thuringia, which corresponds to 2.8 billion Euros (LEG Thuringia, 2015, Statista 2016). A special focus is on the roughly 1,300 employees that work in a multitude of public or private research institutes and doing research in this field of study (LEG Thuringia, 2015). Particularly Jena is characterized by a high degree of innovative activity due to a high share of employees working in research and development (Stifterverband für die Deutsche Wirtschaft, 2015).

Medical technology is another cluster that can be identified in the Jena region. Global-players such as Carl Zeiss Meditec AG, Alere Technologies GmbH and Analytik Jena AG are situated in the Jena region. But also a large number of small- and medium-sized firms operating in the industries of medical technology provide products and services in the field of medical science. In sum, all these firms generate an annual revenue of more than 1 billion Euro in Jena only (Jenawirtschaft, 2014).

3. Knowledge Capital Stock and its Effect

As this thesis aims to give a comprehensive analysis of the economic effect of Jena University on the regional economy, a two-step approach is applied bringing together macro- and micro-economic perspective. In this first step, the macro-economic effect of Jena University in terms of human and research capital flows into the regional economy will be analyzed. The purpose of this is to quantify and analyze the overall macro-economic effect of Jena University.

While the economic demand effects generated by a university can be estimated rather precisely and reliably, the volume and impact of a university´s knowledge capital stock is hardly observable. That is why in the following it will be made use of the production function approach to calculate the knowledge capital stock and its regional effect (Taurus, 2007; Giesecke & Madden, 2006; Pfähler et al. 1999; Guellec et al. 2001; Del Barrio-Castro & Garcia-Quevedo, 2005). The stock will be assessed by the past investments in research and human capital at Jena University. This means that all research and training activities will be regarded as input for the knowledge capital stock. The current expenditures (Grundmittel) of the university are divided into expenditures for research and expenditures for teaching, with external funds fully attributing for research. The fundamental assumption is that the higher the expenditures for research and training, the higher the stock of knowledge capital. Besides the expenditures, other parameters have to be taken into account when estimating the volume and impact of the knowledge capital stock. These parameters will be discussed and outlined in the following and include depreciation rate, operational lag, marginal productivity of knowledge capital, adjustment for inflation as well as the regional share of the economic effect.

The data applied in the following has been collected by Jena University and provided by DIW Econ Berlin. It contains information on financial data such as expenditures and received funding from 2000 to 2013. For that reason, the knowledge capital stock will be estimated with an initial stock starting in 2000 continuing to 2013 and assessing the regional effect of the knowledge capital stock in the year 2013. The applied assumptions are taken form relevant literature as discussed in the following. In order to calculate the regional domestic product, data from the German Statistical Office has been used.

3.1. Methodology and Assumptions

3.1.1. Parameters

Depreciation rate

Just as physical capital also human capital and research capital become obsolete and outdated – new technologies arise, requiring different skills and knowledge bases. That is why it is essential when applying a production function, to take into account that the utilized capital depreciates. Therefore, an annual depreciation rate has to be applied. In the case of research capital most studies set an annual rate between 10 and 30 percent (Argote & Epple, 1990; Esposti & Pierani, 2003; Giesecke & Madden, 2006; Taurus, 2007; Hall et al. 2010; Nemet, 2012). In the following calculation an annual depreciation rate of 15 percent for research capital will be assumed.

In the case of human capital, the examined literature features depreciation rates from 1 to 17 percent per annum. Groot (1998) created a model to calculate the rate of depreciation on human capital in Great Britain and the Netherlands, which does not take into account neither individuals' potential earnings nor the investment in human capital after entering the labor market. He found that the rate of deprecation of education is between 11-17 percent per year. More recent studies from Spain and Switzerland include both, investment in human capital after incorporation in the labor market as well as potential earnings, and therefore give a different picture. A depreciation of human capital in a narrow interval centered around 1 percent per annum has been identified for Spain (Arrazola & Hevia, 2004; Arrazola et al. 2005). In the case of Switzerland, Weber (2014) obtained a depreciation rate of 0.6 to 0.7 percent for general education and 0.9 to 1 percent for specific education including academic training. As it is assumed in this calculation that potential earning of professionals will increase in time as well as there will be further investment and knowledge gain after entering the labor market, these estimations will follow Arrazola et al. (2005) and Weber (2014) by applying a depreciation rate of human capital of 1 percent per annum.

Operational Lag

As it takes time between the creation of knowledge at universities and its economic commercialization by entrepreneurs and enterprises, an operational lag has to be assessed. In the examined literature an operational time lag of 1 to 8 years is applied (Del Barrio-Castro & Garcia-Quevedo, 2005; Adams et al. 2006; Taurus, 2007; Ljungberg & Nilsson, 2009). Due to the sound interconnections of Jena University and the surrounding regional economy, an operational lag of 3 years will be applied. This length of operational lag for tertiary or higher education can be underpinned empirically by Ljungberg and Nilsson (2009), who found statistical significance in their analysis of the Swedish human capital development since 1870. An operational lag of 3 years means that in 2013 the knowledge capital stock of 2010 takes effect.

Marginal Productivity of Knowledge Capital

To study the economic impact of the knowledge capital stock generated at Jena University, the marginal productivity of capital has to be considered. The marginal productivity states how much the output will increase, in case the input factor (labor, capital, knowledge) is increased by one unit while the other input factors stay the same. Based on Giesecke and Madden (2006) the marginal productivity of knowledge capital is assumed to be about 0.5. Meaning that an increase of the knowledge stock by one Euro, the gross value added increases by 0.50 Euro.

Adjustment for Inflation

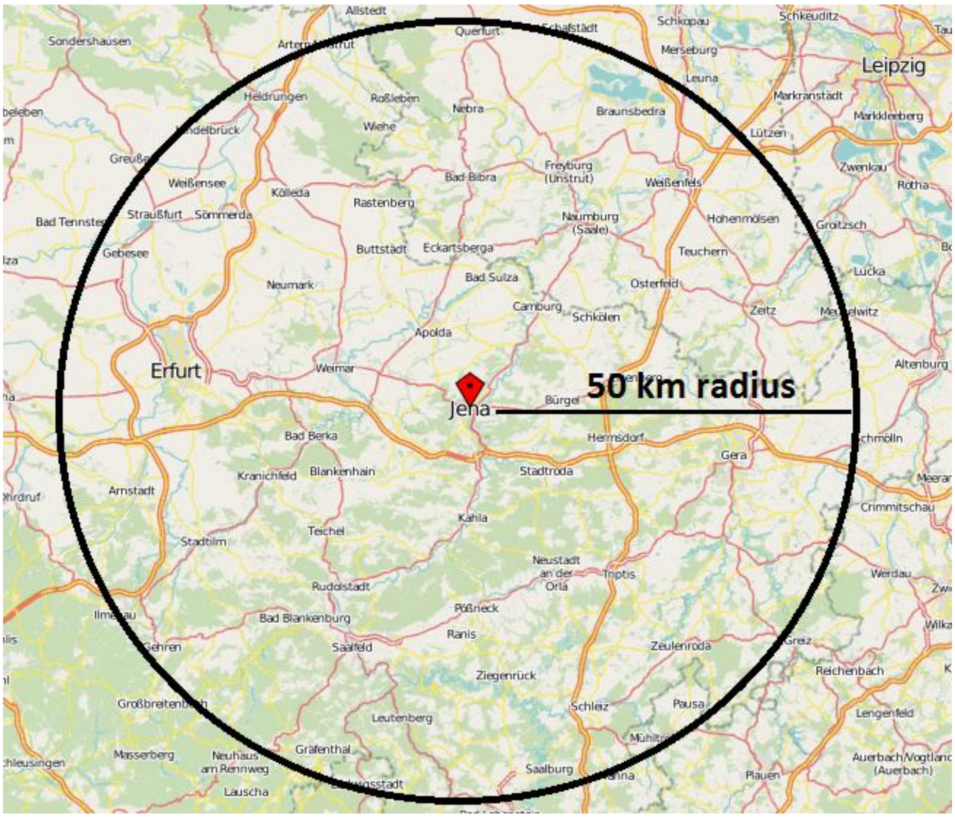
The expenditures for research and training, which are considered as input of the knowledge stock will be adjusted for inflation. This will be done by using a deflator for the German GDP on base of 2013, which is provided by the International Monetary Fund (2014).

3.1.2. Regional Impact

The regional effect of the knowledge capital stock generated at Jena University can be divided into the effect of the human capital and the research capital stock. Each stock creates different effects in terms of capital flows on the regional, transregional and international level. In this analysis special attention is given to the regional effect. Any effects on the region´s human capital and research capital endowment from outside the region will be blanked out. The only effect that is considered is the effect generated at Jena University. This is due to the fact that Jena University is the only full-scale-university in the region and by far the biggest generator of human capital in terms of university graduates in the Jena region; but also in terms of research capital generation Jena University is one of the few big actors. Therefore, from a macro-perspective this is a unilateral treatment. This should be kept in mind.

The geographical range of knowledge transfer and the economic impact have been subject to a huge body of studies. One of the main findings is that knowledge generated at a university, mainly affects the surrounding region (Niebuhr, 2000; Peri, 2005; Fritsch & Slavtchev, 2007; Andersson et al. 2009; Belenzon & Schrankerman, 2010). From an economic point of view, this phenomenon is caused by the low costs for transaction and acquisition of knowledge in close proximity to a university (Blume & Fromm, 2000). As a proxy for knowledge it is common to use patents, though there are limitations to this approach. This issue will be discussed extensively in section 5.1.1. In accordance with Fritsch and Slavtchev (2007) who detect that the economic impact of universities becomes operative in a radius of 50 kilometers, Jena region is defined as the area in an about 50 km radius around Jena. Below the map illustrates Jena region, which also includes the state´s capital Erfurt and cities like Weimar and Gotha.

Figure 2: Display of a 50km-range around Jena



Source: OpenStreetMap (2016). Author´s illustration.

The regional impact of human capital generated at the Jena University is approached by the ratio of graduates that stay in the Jena region after graduation. According to a recent study on the mobility of university graduates in Germany, 32.9 percent of the Thuringia graduates stay in the Freistaat for work (Haussen & Übelmesser, 2015). About two thirds leave the state of Thuringia and also Jena region. Consequently, graduates of Jena University that leave the region, carry their knowledge and skills into different regions in Germany and abroad. Of the 67.1 percent of graduates that left the region, 4.7 percent moved abroad. Moreover, the study concluded that who once left Thuringia will return with a low chance of 4 percent after 5 years.

With the findings of the examined literature on the geographical range of knowledge transfer in mind, it is reasonable to argue that the ratio of regional and trans-regional patent cooperation can be regarded to as a proxy for the geographical ratio and allocation of knowledge. The analysis on the patenting activities of Jena University showed that 59.6 percent of joint patent applications have taken place with a regional partner. 40.4 percent of the joint patents have been applied for with partners outside Jena region. Consequently, these findings will be used as proxy for the allocation of the economic effect that is generated by the research capital stock and spilt into the different geographical levels of impact.

3.2. Calculation of the Knowledge Capital Stock

After presenting and discussing parameters applied and assumptions made, the individual steps of the calculation will be outlined. In order to estimate the knowledge capital stock, the stock of human capital and the stock of research capital have to be calculated. However, due to shortage of data only dating back to 2000, an initial stock has to be started with. First, the initial stock of human capital in year 0 (t=0) corresponding to 2000 will be estimated. This capital stock (T_0) is the result of the expenditures in t_0 divided by the depreciation rate of human capital (d_t) and the average growth rate of expenditures for training in the first 10 years of available data. This corresponds to the average growth rate of the expenditures for training in the years 2000 to 2009. The same procedure is applied in a second step to estimate the initial stock of research capital (R_0). With r_0 representing the expenditures for research, d_r the research capital specific depreciation rate and w_r constituting the average expenditure in research in the first 10 years.

$$T_0 = \frac{t_0}{d_t + w_t}$$

$$R_0 = \frac{r_0}{d_r + w_r}$$

For every following year, each year´s expenditures in training (t_t) and research (r_t) after clearing for inflation by dividing with a deflator in year t (i_t) are added to the previous year´s stock of human capital (T_{t-1}) and stock of research capital (R_{t-1}), which is depreciated with the specific depreciation rate for human capital and research capital.

$$T_t = \frac{t_t}{i_t} + (1 - d_t) * T_{t-1}$$

$$R_t = \frac{r_t}{i_t} + (1 - d_r) * R_{t-1}$$

By adding up the stock of human capital in year t (T_t) and the stock of research capital in the year t (r_t) the stock of knowledge capital in year t (K_t) is generated.

$K_t = (T_t + R_t)$

To estimate the economic effect, the knowledge capital stock has to be multiplied with the marginal productivity of knowledge capital (m). Due to the operational lag of 3 years, K_{t-3} is the appropriate knowledge capital stock for year t.

$E_t = K_{t-3} * m$

To calculate the regional impact of the knowledge capital stock that is generated by the university the regional rate of human capital (here: 32.9 percent) as well as the regional rate of research capital (here: 59.6 percent) are applied. A similar procedure is used to estimate the national and international effect of the knowledge capital stock. See Appendix B for an extended overview of all parameters used for the knowledge capital stock calculation.

4. Results and Discussion: Quantifying the Economic Effect

With the help of an estimated knowledge capital stock it is attempted to quantify the economic effect of Jena University on the regional economy in terms of research and human capital flows. As outlined earlier, the volume of the knowledge capital stock is estimated by accumulating and depreciating the past investments (expenditures) in research and teaching at Jena University. This means that research and teaching activities of the university are recognized as input factors for the knowledge capital stock. Taking into account the annual depreciation rate, the human capital stock as well as the research capital stock are calculated. Both stocks add up to the knowledge capital stock.

4.1. Knowledge Capital Stock

	expenditures for teaching	expenditures for research	human capital stock	reserach capital stock	knowledge capital stock
2000	64,780,223	60,161,054	1,267,369,835	282,589,198	1,549,959,032
2001	69,772,346	60,770,850	1,324,468,483	300,971,668	1,625,440,151
2002	68,737,601	65,145,391	1,379,961,399	320,971,309	1,700,932,708
2003	70,515,709	63,347,019	1,436,677,495	336,172,632	1,772,850,126
2004	71,053,361	64,529,640	1,493,364,081	350,276,377	1,843,640,458
2005	72,979,053	67,376,836	1,551,409,493	365,111,757	1,916,521,250
2006	73,669,459	71,332,838	1,609,564,857	381,677,831	1,991,242,689
2007	72,453,695	80,840,072	1,665,922,904	405,266,229	2,071,189,132
2008	79,678,928	88,128,778	1,728,942,603	432,605,073	2,161,547,675
2009	89,519,886	98,579,930	1,801,173,063	466,294,242	2,267,467,305
2010	95,976,519	109,509,544	1,879,137,851	505,859,649	2,384,997,500
2011	110,823,880	122,216,400	1,971,170,353	552,197,102	2,523,367,454
2012	112,684,167	126,148,807	2,064,142,816	595,516,343	2,659,659,159
2013	118,811,308	139,264,830	2,162,312,696	645,453,722	2,807,766,417

Table 2: Expenditures and Capital Stocks from 2000 - 2013 (in 2013 Euros)

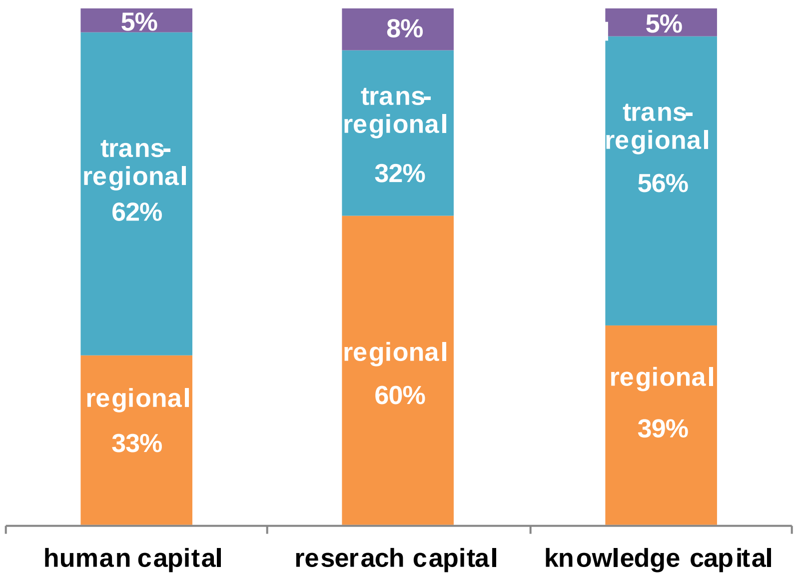
Source: Jena University (2016). Author´s calculation.

Table 2 displays the expenditures for teaching and research as well as the human, research and knowledge capital stock for the years 2000 to 2013. Due to limitation in available data, only investment and capital stocks since 2000 are presented. In the case of research capital, the effect of investments that have been made before 2000 barely have any impact in 2013. For instance, one Euro that was invested in the research capital stock in 2000 decreased to a few cents by 2013 due to the assumed high depreciation rate of research capital. On the contrary, human capital investment before 2000 still has an impact in 2013 as its depreciation rate is rather low. Not only because of this issue, but also in order to better reflect reality these calculations are based on an initial human and research capital stock. Both initial stocks have been calculated as outlined in section 3.2. An initial research capital stock of 283 mil Euro and an initial human capital stock of 1,267 mil Euro have been estimated in 2000.

Between 2000 and 2013 both, annual expenditures for teaching as well as research increased from 65 mil Euro to 119 mil Euro and from 60 mil Euro to 139 mil Euro, respectively. The main reason for the rise in expenditure for these activities is that in the same period of time the number of students and academic staff have also increased significantly. It is a general trend that has been observed all over Germany in the past decade due to "academization" of an immense share of the population (Wolter & Kerst, 2015). As a result, the knowledge capital stock increased significantly from 1.5 billion in 2000 to 2.4 billion in 2010 and 2.8 billion in 2013. When considering the growth rates of each capital stock, notable findings arise. While the research capital stock made out 18.2 percent of the knowledge capital stock in 2000, the share rose to 22.9 percent in 2013. This translates to an increase of about 128 percent (6.5 annually) for research capital over this period, compared to roughly 71 percent (4.2 annually) for the human capital stock – despite the significantly higher depreciation rate for research capital. One reason for this is the increase of expenditures for research of about 232 percent over this period, while the expenditures for teaching rose by about 183 percent.

4.2. Regional Growth Effects

Figure 3: Allocation of Economic Effect to Geographical Scales (regional, transregional, abroad)

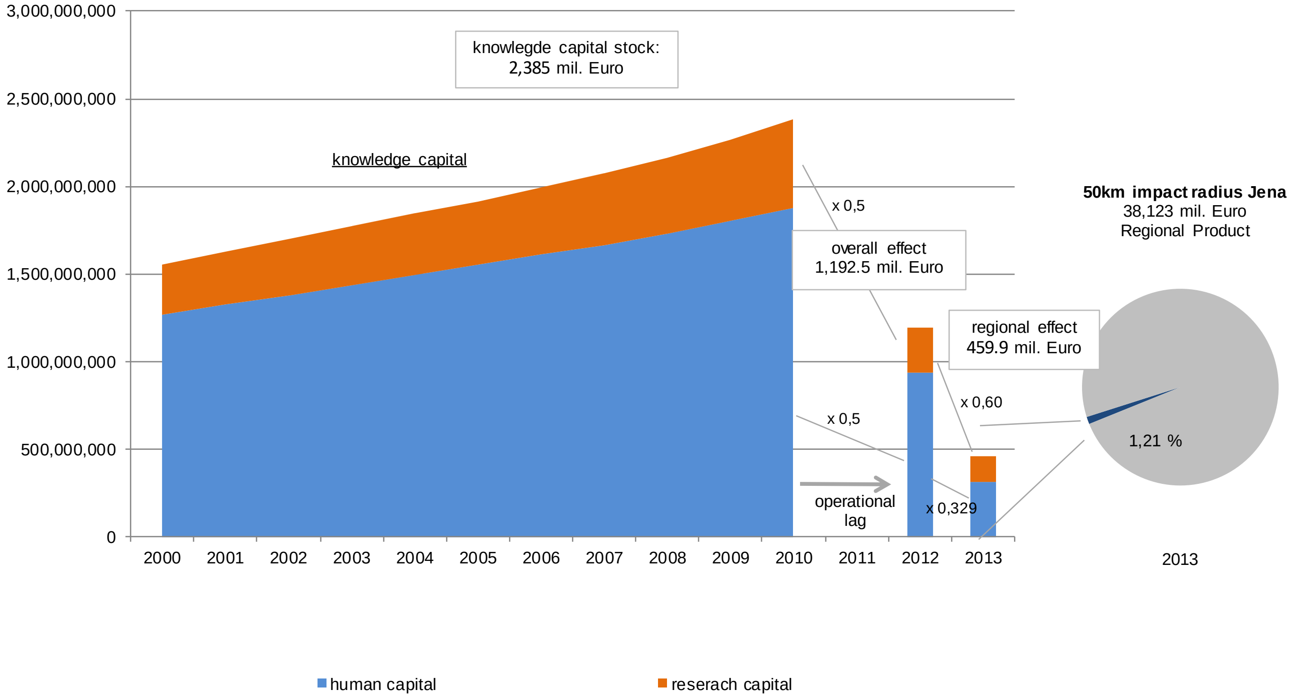


Source: Jena University (2016). Author´s calculation.

In order to estimate the regional growth effects in terms of capital flows that are initiated by the knowledge capital creation of Jena University, the assumptions outlined earlier are applied. Meaning that in 2013 the growth effects of the capital stock of 2010 take effect. The regional rate of the effect of the knowledge capital is about 38.6 percent. Consequently, the teaching activities of Jena University contribute roughly 309.1 mil Euro and the research activities contribute about 150.7 mil Euro to the regional economy. In sum, this leads to a total regional impact of about 459.9 mil Euro that is generated at Jena University. Moreover, there are effects created that outreach the regional level. About 667.5 mil Euro of knowledge capital flows take effect in Germany outside Jena region and about 65.2 mil Euro have an effect on the international level. For an extensive list see Appendix B.

The expenditures for training and research since 2000 created a knowledge capital stock of 2,385 mil Euro in 2010, as illustrated in Figure 4. In 2013 the effect of this knowledge capital stock comes into operation and generates total growth effects of 1,192.5 mil Euro of which 459.9 mil Euro affect the Jena region. In other words, putting the regional effect in comparison to the regional domestic product; the regional effects of knowledge capital of roughly 460 mil Euro created at Jena University correspond to 1.21 percent of the Jena region´s domestic product in 2013 (German Statistical Office, 2016).

Figure 4: Knowledge Capital Stock and Regional Growth Effects in 2013 (in 2013 Euro)



Source: Jena University (2016). Author´s calculation.

Note: Knowledge capital stock since 2000 and regional human and research capital flows in 2013 (both in 2013 Euro) and share of regional product of Jena region in 2013 that correlates to regional effect of Jena University

When quantifying the economic effect of Jena University on the Jena region, it has been revealed that 38.6 percent of the effect of the knowledge capital stock, which corresponds to a total effect of 459.9 mil Euro is operative in the Jena region in 2013. Due to the huge number of university graduates that leave the region after graduating university, the effect of human capital that is created at Jena University remains rather low in relative terms. However, comparing the effect of human capital of roughly 310 mil Euro in absolute terms to the regional effect of research capital of about 151 mil Euro, the regional effect of human capital is more than twice as big. Consequently, from a policy-point of view, efforts in making graduates stay in the region after graduation lead to more efficient growth effects than efforts in an increase of the regional effect of research capital.

It is necessary to also point out the limitations of the applied production function approach to estimate the knowledge capital stock and its regional effect. Generally speaking, the outlined estimations are a simplified depiction of a rather complex and abstract process, which cannot be analyzed in detail in this paper. Due to limitation of the available data, only expenditures since 2000 could be drawn back. All prior investment in the knowledge capital stock had to be calculated with the help of an initial stock. Moreover, the applied parameters are up for discussion. As it has been outlined and discussed in section 3.1., there usually exists quite a fair range of different ratings of each parameter and assumption that has been made in this analysis. In particular, the determination of the depreciation rate has a significant impact on the results received. Nevertheless, the results give an idea of the effect and the importance of Jena University for the regional economy.

4.3. Bridging the Gap: From Macro- to Micro-Perspective

After quantifying the macro-economic effect of Jena University, it became obvious that the university plays an essential role for the regional economy in terms of creating and transferring knowledge, human and research capital to firms and institutions nearby. But what exactly does this mean? How does this effect of Jena University contribute to the real (micro) world? For that reason, now emphasis will be given to the micro-economic effect and contribution of Jena University to the regional economy. Moreover, as the aim of this thesis is to deliver a comprehensive analysis of the economic effect of Jena University, an examination of mechanisms how the university affects surrounding actors is essential for a better understanding of the economic impact. The purpose here is to underline and illustrate the found macro-economic importance of Jena University with micro-economic evidence.

5. Patenting Activities and Research Cooperation

From a micro-perspective it is attempted to reveal how knowledge is transferred from Jena University to the regional economy and its firms. Thereby, exemplarily patent cooperation will be examined with the objective to assess patterns, intensity and the technological focus of patents emerging from research cooperation. What patterns can be revealed in joint patent applications of Jena University and regional actors? What are the technological fields of cooperation? Does this reflect the region´s technological endowment? And what role do Jena University's spin-offs play in this process? In order to answer these questions, knowledge transfer and research cooperation will be examined by applying a patent data analysis. The study is based on an approach by Fraunhofer Institute for Systems and Innovation Research (Dornbusch et al. 2012) to identify not only university-owned, but also university-invented patents. By doing so, patent linkages and cooperation will be described quantitatively and qualitatively.

5.1. Patents in the Literature

A patent is a timely limited grant given by a patent authority for a certain geographical range and time, in order to protect a certain technology or invention and allow a monopole on the use and commercialization of it. Hereby, the applicant is enabled to secure outcomes and results of a research or development process. In return, the technology has to be described and bared (Adams et al. 2006). Due to this trade-off between baring sensible information and a timely limited monopoly position, a patent system can be regarded to as an incentive-mechanism for creating economically valuable knowledge and as a knowledge-diffusion mechanism to disseminate newly gained information (Smith, 2006). The past 20 years have seen a significant increase in patenting activities. Smith (2006) explains this by an acceleration of innovation efforts, changes in the strategic behavior of private enterprises and a significant reduction of patenting costs. Worldwide more than 70 million patent registrations exist in the various technological areas (OECD, 2015).

5.1.1. Patents as Indicator for Knowledge Transfer

Using patents as an indicator for knowledge transfer offers benefits, but also limitations. First of all, strong requirements for patent registration and the control of independent patent registration organizations lead to a high reliability of patent data. At the same time, patent data contains a huge amount of information on different aspects related to the patent. This gives obvious advantages as a proxy for knowledge transfer and innovation. There are three advantages for applying a patent data analysis in this thesis: First, patent data systematically records extensive information about applicants and inventors, information on the technology or the innovation that is protected by the patent. Second, all patents are organized in a technology classification system, which enables relating inventions to relevant technologies and also offers connections to linked technical and scientific literature due to citations. Third, patents are acknowledged for innovative technologies with promising commercial success (Smith, 2006).

Using patents as a proxy also has its weaknesses. The maybe most serious weakness of using patents as an output indicator is that patents are more a proxy for invention than for innovation, Smith (2006) points out. Patents denote the rise of a new technology, not a commercial innovation. A huge number of patents refers to inventions that are actually of little commercial importance. Moreover, Kleinknecht et al. (2002) argue that patent indicators miss a huge number of non-patented inventions and innovations. Furthermore, certain types of technologies and inventions are not patentable, but licensed or trademarked instead (Dornbusch et al 2012). Consequently, it is likely that there is quite a significant share of inventions that is never turned into a commercially successful innovation.

Nevertheless, as the main focus here is given to collaboration and cooperation between Jena University and its research partners in terms of knowledge transfer, commercial success of a patent is of minor interest, though still relevant in explaining the role of Jena University in the regional economy. Therefore, it is argued that in this case, patents as proxy for knowledge transfer and flows in joint patent applications are justifiable. Moreover, patent indicators have shown to be appropriate indicators for studies focusing on knowledge transfer. The indicator has been used for the mapping of inter-industry technology flows (Scherer, 1982) as well as the analysis of knowledge spill-overs using patent citations (Jaffe, Henderson & Trajtenberg, 1997). Also patents have been used as a measure of university “output” (Jaffe, 1989; Henderson, Jaffe & Trajtenberg, 1998) and particularly patent citation data has been used to study university innovation and collaborations (Agrawal & Henderson, 2002; Jaffe, Trajtenberg & Henderson, 1993; Jaffe, Fogarty & Banks, 1998; Jaffe & Trajtenberg, 1996).

5.1.2. Measuring and Analysing Academic Patent Activity

Measuring and analysing academic patent activity is a difficult and complex undertaking. This is particularly the case with analysing German academic patent data. The main issues in this case it the deficiency of a well-established and sound approach to identify academic patents that have not been applied for by the university itself, but by other institutions, firms and organizations or by the inventor himself (Dornbusch et al. 2012). While the US introduced the Bayh-Dole Act in 1980, most European governments moved away from issuing individual ownership of academic patents towards university ownership since the late 1990s. Germany abolished the traditional professor´s privilege (Hochschullehrerprivileg) in 2002 and introduced policies similar to the US (Geuna & Rossi, 2011). As a result, every innovation and new technology that was generated or invented by an employee was no longer owned by the individual, but by the employing university. Financed research, however, represents an exception, for which it is still possible to negotiate patent rights between the financing organization, the employing university and the researcher.

In order to analyse German academic patent data, it is necessary to take the different typologies of university-based patents into account. The applied typology will follow Meyer (2003), who defines "university-owned patents" as those patents, which have been applied for by the university itself and consequently the university or its technology transfer office is listed as applicant. On the contrary, "university-invented patents" are patents, that list university affiliated authors as inventors. This means, that the applicant is a third party, for instance a private enterprise, a research institute or an individual inventor. Both types of patents taken together are considered as university-based or "academic patents" (Lissoni et al. 2008). In the analysis of academic patents, particularly the identification of university-invented patents represents a rather complex and problematic issue. For that reason, it often remains a gap in the study of universities´ patenting activities.

European and in particular German universities still lack patent application activities. A study by Thursby et al. (2009) shows that most of the patents in Europe are allocated at private enterprises and organizations. The contrary is the case in the United States, where more than 62 percent of all patents are owned by universities. As a result, a significant share of patents that are university-invented is not filed by the universities themselves in Europe and Germany. Although there have been various attempts to improve systematically identifying academic patents, particularly university-invented patents, there are two main issues persisting still. On the one hand, a huge number of university-invited patents are applied for by private enterprises as a result of research cooperation with firms. On the other hand, there are still cases in which inventors apply for patenting as an individual and are assigned as the applicant of a patent (Geuna & Rossi, 2011).

5.1.3. Approaches to Identify University-invented Patents

As it became clear, the main issue of analysing academic patenting activities is to identify university-invented patents; those patents that universities themselves have not applied for. On the contrary, university-owned patents are easily to identify as the names of applicants are revealed in every patent file and can be found by name search. However, only analysing patent data by cursory searches for academic institutions or university names does not barely mirror a university´s patenting activities. It does simply not capture the number of university-invented patents and therefore significantly underestimate the actual count of patents. For that reason, it is essential in aiming for a comprehensive account of a university´s patent activity to focus on identifying names of a university's researchers and scientist, who are also listed in the patent databases as inventors.

Two different approaches to identify university-invented patents have been established in the past years. The first approach is to simply search for keywords. This idea is very common in Germany as in official documents such as a patent application the academic title is usually given, though it is not part of the name. This way university-invented patents can be identified by searching for academic titles such as PROF, UNIV PROF or PROFESSOR. This approach has been applied widely for analysing German academic patent activities (Schmoch, 2007; Czarnitzki et al. 2007, 2011; von Ledebur, 2009; von Proff, 2011). The other approach is based on matching lists and bringing together authors and inventors. The attempt is to match staff name lists of a university with inventor data on certain patent specification. This approach dates back to earlier projects of Noyons et al. (2003), who collected relevant publications in the fields of life science and nano-technologies and combined them with patent registrations at the European Patent Office (EPO) and the World Intellectual Property Organization (WIPO). On base of the technological specification they merged authors and inventors. Thursby et al. (2009) used this approach for the US and Lissoni et al. (2008, 2009) applied this approach for Italy, France and Sweden in the KEINS project (Knowledge-based Entrepreneurship: Innovation, Networks and Systems).

According to Dornbusch et al. (2012), both outlined methods to identify university-invented patents provide pragmatic and sound results. However, they also hold some limitations and weaknesses, which have to be point out before proceeding. In particular, the search for academic titles is restricted to Germany and Austria, where it is common to indicate academic titles like “Professor”. Yet, those titles are not designated at the EPO, but only at the German Patent and Trade Mark Office and the Austrian Patent Office. Furthermore, and even more problematic is that this approach does not cover any other university staff member such as research fellows and PhD students that acts as an inventor of a patent. Besides that, not every professor is indicating the academic title when applying for a patent; and as Dornbusch et al. (2012) point out is the number of professors citing their title decreases at least in Germany. Therefore, applying this approach will lead to an underestimated number of patents.

The main issue with the matching approach is that creating and setting up a university’s staff list is a very time-extensive and comprehensive task as this data is generally hard to find. One reason for this is that in some countries there are no comprehensive lists of university staff existing. Consequently, these had to be created and updated with the help of the respective university. If such lists do exist, they may only feature specific groups of staff such as employees with a secure status like tenured professors (Dornbusch et al. 2012).

5.2. Data

The patent data analysis examines patents applied for at the European Patent Office (EPO). Patent applications at the EPO and not the German Patent Department will be used as commercial success of patents registered at EPO is supposed to be higher than at the German Patent Department. The patent data used in this study is provided by the PATSTAT database and REGPAT database, which both cover applications at the EPO. Also data on affiliated authors is provided by SCOPUS.

The “EPO Worldwide Patent Statistical Database" PATSTAT is offered by the EPO, which provides information on about 70 million patent applications collected from about 90 countries worldwide. PATSTAT is updated every six months (EPO, 2016). The REGPAT database is provided by the OECD and presents patent data that has been linked to regions according to the addresses of the applicants and inventors. The data has been rationalised at a very detailed level so that more than 2,000 regions are covered across OECD countries (OEDC, 2008). Both, PATSTAT and REGPAT are relational databases, which are run for statistical analysis only. The databases or parts of them have to be saved on an individual server and can only be accessed by tools of relational databases. For the present thesis, Microsoft SQL Server has been used, which runs on SQL-Queries. For information on how the relational database was set up, see Appendix C.

Data on publications and author names has been used from SCOPUS. The database is provided by Elsevier, which offers information on articles and papers in about 21,500 peer-reviewed journals and other titles from trade publications, book series and conference papers. SCOUPS is updated every year (SCOPUS, 2016).

5.3. Methodology

The following patent data analysis consists of two parts: the identification of university-owned patents and the identification of university-invented patents. The first one is performed by searching for keywords. The second one is more difficult. The identification of university-invented patents is a two-step process and is guided by an approach that has been introduced by the Fraunhofer Institute for Systems and Innovation Research (Dornbusch et al. 2012). The first step, which is regarded to as *parsing stage* (Raffo & Lhuillery, 2009) consisted of constructing an appropriate database by preparing information required into tables in a relational database. With the help of Microsoft SQL Server, the data has been cleaned and harmonized. The second step, which is regarded to as *matching and filtering stage* (Raffo & Lhuillery, 2009) consists of the actual matching process. In this step, the names of inventors and authors are matched and filtering criteria is applied to increase the accuracy of the matching process. Finally, both sets of patent data are merged, duplicates are cleaned out and the final patent evaluation of cooperation and regional impact is conducted.

5.3.1. Identification of University-owned Patents

First, university-owned patents have been identified, those that have been applied for by Jena University. This has been done by a keyword search. The following specification have been applied: First, the patent had to be applied for by an applicant (pa.invent_seq_nr = 0) whose name was the one of Jena University. As there are different forms of this name existing, various versions have been searched for (e.g. p2.person_name LIKE '%UNI%JENA%). Also it had to be specified that only patents applied for at the EPO have been included (i.appln_auth = 'EP'). An example query is illustrated in Box 1 below. By connecting the different tables via JOIN-function and searching for different forms of spelling of the Friedrich-Schiller University Jena via LIKE-function.

```sql
SELECT *
FROM tls206_person p
JOIN tls207_pers_appln pa ON p.person_id = pa.person_id
JOIN tls201_appln i ON pa.appln_id = i.appln_id
WHERE pa.invt_seq_nr = 0
AND i.appln_auth = 'EP'
AND pa.appln_id IN
             (SELECT a2.appln_id
             FROM tls201_appln a2
             JOIN tls207_pers_appln pa2 ON a2.appln_id = pa2.appln_id
             JOIN tls206_person p2 ON pa2.person_id = p2.person_id
             WHERE p2.person_name LIKE '%UNI%JENA%'
             or p2.person_name LIKE 'uni%jena%'
             or p2.person_name LIKE 'FSU'
             or p2.person_name LIKE 'univ%jena'
             (AND a2.earliest_filing_year >= 1950
             AND a2.earliest_filing_year < 9999))
ORDER BY i.appln_id
```

Box 1: Example Query to Identify University-owned Patents of Jena University

5.3.2. Identification of University-invented Patents

The first step, which is regarded to as *parsing stage* (Raffo & Lhuillery, 2009) was to construct an appropriate database by preparing information required and extract information on authors affiliated with Jena University from the SCOPUS database. SCOPUS data consisted of information on affiliated authors´ names and year of publication. In order to reduce noise and data volume, data has been prepared by cleaning unwanted information without removing any essential information that might be helpful at a later point. Different parsing strategies have been applied and the following seemed to be most appropriate in respect to keep the subsequent matching precise. All dots, symbols and blanks have been removed. Moreover, it had to be dealt with a specific characteristic of the German language: All umlauts had to be replaced (e.g. ä > ae, ö > oe, ü >ue).

The second step, which is regarded to as *matching and filtering stage* (Raffo & Lhuillery, 2009) consists of the actual matching process. In this step, the names of inventors and authors are matched and selection criteria is applied to increase the accuracy of the matching process.

Selection Criteria

Due to the fact that one name might link to several authors and academic staff, and therefore create serious errors and mismatches, further selection and matching characteristics have to be taken into account. The determination of these factors has to be the information provided by the patent databases PATSTAT and REGPAT as well as the publication database SCOPUS. The following criteria have been applied:

1. Country
2. University
3. Name
4. Region
5. Point in time

Country: In the case of authors, SCOPUS provides the county of the employing institution or university. In the case of inventors, PATSTAT and REGPAT offer information on the country of residence. In some cases, this might be the address of the employing organization.

University: With SCOPUS it is possible to only select authors, which are affiliated with a certain university. In the case of some countries, one has to check for different forms of the university name. For Jena University, however, there is only one form of the university name and therefore identification in SCOPUS was unproblematic.

Name: In the databases PATSTAT and REGPAT surnames as well as full first names are listed. The reason for this is that patent applications are official documents. Also SCOPUS offers information on full first and surname that date back to 1996.

Region: One option is the use of postal codes to select a region. The idea of using postal codes is, that university staff usually lives in geographical proximity to the employing university. Dornbusch et al. (2012) found out that in Germany 88 percent of inventors´ places of residence have the same first two digits of the postal code as the employing university. Using only the first digit of the postal code revealed a match of 98 percent. The issue with applying this criterion for Jena is that there is a change of postal code´s first digit westwards right next to the city of Jena. For that reason, in this analysis NUTS3-level regions have been used as geographical units. The selected NUTS3-regions are located in maximum commuting distance, which corresponds to a radius around Jena of about 50 kilometres. Appendix A displays the NUTS3-regions defined as Jena region.

Point in time: Generally, there has to be a time-wise connection between the date of publication and the date of patent registration. However, one has to be very cautious by applying certain periods of time and assuming time shifts between date of publication and date of registration. As a time reference Dornbusch et al. (2012) suggest applying the priority year, which is the first filing of a patent. According to the OECD (2008) this is the closest to the actual date of invention. Due to that fact, this date should be applied as reference when collection patent indicators. The other dates (application date, publication date, grant date) depend on country-specific or administrative norms and procedures. Therefore, these dates can be one to ten years after the actual invention and for that reason delude the results. In the case of patent registration, it is assumed that the creation of the invention took place just before applying for a patent.

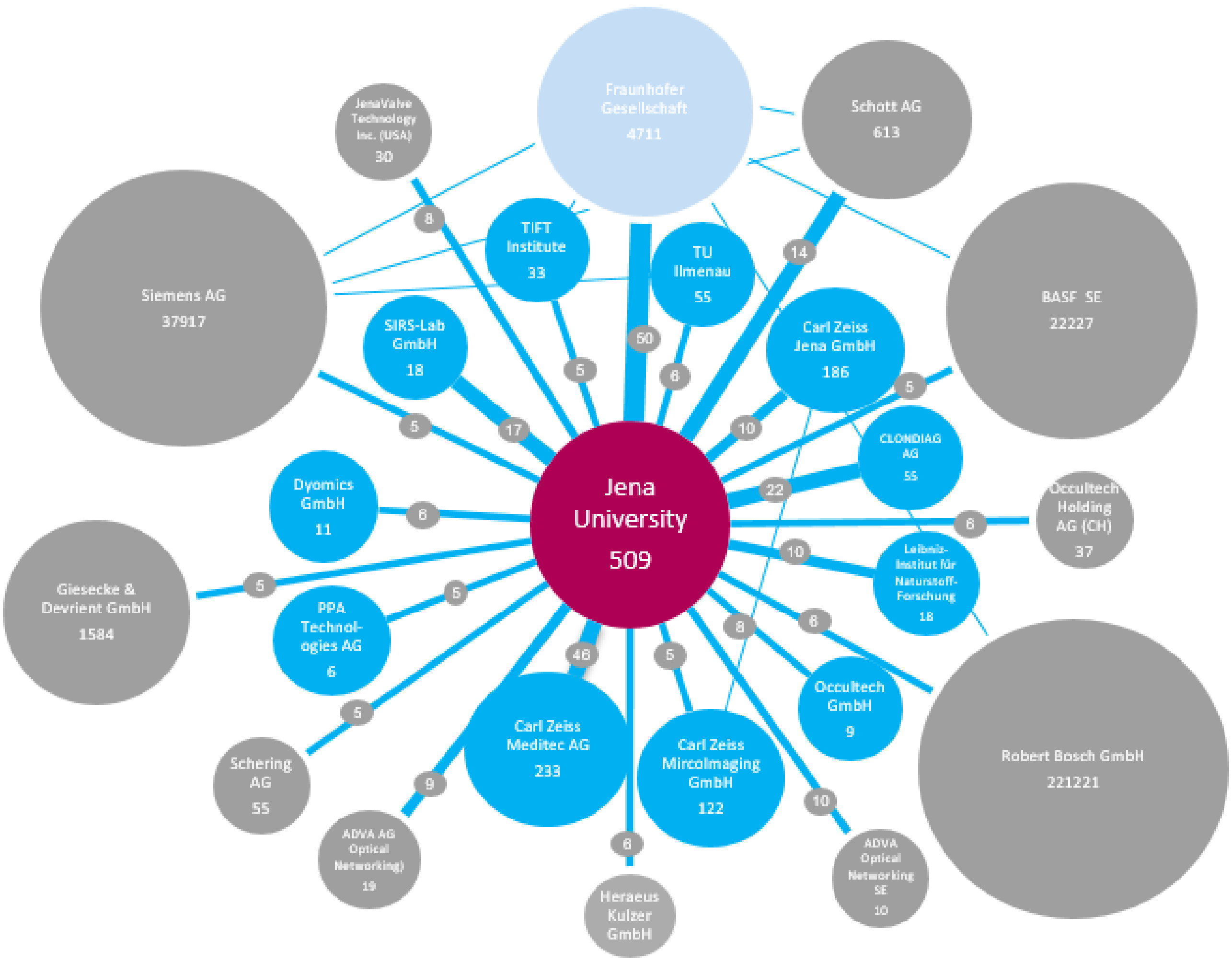
In the case of publications, it is common to analyse by the year of publication. In order to match data on publications with data on patents, it is important to keep in mind that there is also a time lag between submission and publication of academic papers due to peer-reviewing and editing. In this case a time lag of one year is assumed (Dornbusch et al. 2012). These circumstances result in an essential matching criterion. In the present analysis the year of publication will be matched with a patent filing in the year of publication and the year proceeding that one. This means an author´s name is not just sampled with the year of publication and a filing in the year of the publication, but also a filing in the year before the publication. Finally, both obtained sets of patent data are merged and duplicates removed. With the help of Excel, the final evaluation takes place.

6. Results and Discussion: Patents and Knowledge Transfer

6.1. Patterns and Intensity

With the help of a patent data analysis 509 university-based patents of Jena University that have been applied for at the European Patent Office since 1999 have been identified. For a full list see Appendix D. Of these 509 patents 70 have been classified as university-owned patents indicating Jena University or the Jena University Clinic as applicant. Of these 70 patents 44 have been applied for by the university with a partner, 3 in cooperation with the university clinic, 14 by the university only and 7 by the university clinic only as well as 2 by the university clinic and partner. The other 439 as university-invented identified patents have been applied for by private enterprises or research institutes with affiliated staff of Jena University listed as inventors. 488 patents have emerged out of 601 cooperation between Jena University or/ and Jena University Clinic and another research partner or private enterprise. A cooperation here is defined as one participation in the application for a patent. One patent can emerge from more than one cooperation or cooperation partner.

Figure 5: Network Diagram of Joint Patent Applications



Source: OCED (2016), EPO (2016), SCOPUS (2016). Author´s illustration.

As the network diagram above illustrates, Jena University and its staff collaborate with various actors and organizations in the Jena region but also outside of it. The diagram includes every of the 23 cooperating partners that had at least 5 joint patent applications with Jena University or its affiliated staff. The numbers in the grey circles on the connection line between the university and the cooperating actor show the number of joint patent applications. The size of circle reflects the total number of an organization's patent applications, which is also indicated below the name. A blue circle represents a regional partner that is located within the Jena region. A grey circle stands for a partner, which is located outside the Jena region. In the case of an international partner the country where the organization is located is indicated in brackets. The Fraunhofer Gesellschaft represents an exception; therefore, it is light blue. There is a Fraunhofer Institute located in the city of Jena and another one in the Jena region in Hermsdorf, which is about 20 kilometres away from Jena. However, as the headquarter of the Fraunhofer Gesellschaft is located in Munich, every patent is applied for from Munich even if research and development has been done in the Jena region. Therefore, these patents are difficult to allocate.

Of the identified cooperation about 60 percent took place with a regional partner. Another 32 percent took place with a national partner outside Jena region and about 8 percent with a partner abroad. Leaving out the special case of the Fraunhofer Gesellschaft as these patents cannot be precisely allocated, the cooperating partners with by far the most joint patent applications are all three regional partners. This is the case of Carl Zeiss Meditec AG with 46 joint patent applications, CLONDIAG GmbH (now: Alere GmbH) with 22 joint applications as well as SIRS-LAB with 17 patent applications. These three actors also constitute the three most important partners in the private sector on the regional level. On the national level Schott AG with 14 joint applications, ADVA AG Optical Networking based in Martinsried with 10 and ADVA Optical Networking SE based in Meiningen with 9 joint patent applications are the most important partners in the private sector. Internationally, JenaVale Technology Inc. in the USA is the most important partner with 8 joint patent applications. The company has been founded as a spin-off of Jena University Clinic by two professors named Hans-Reiner Figulla and Markus Ferrari. Occultech Holding AG is a spin-off based in Switzerland that has been supported by Prof Hans-Reiner Figulla and features 6 joint patent applications. Imra America, Inc. displays 3 joint patent applications with Jena University.

private enterprises						
regional	Carl Zeiss Meditec AG	46	CLONDIAG GmbH	22	SIRS-Lab GmbH	17
national	Schott AG	14	ADVA AG Optical Networking	10	ADVA Optical Networking SE	9
international	JenaValve Technology Inc.	8	Occlutech Holding AG	6	Imra America, Inc.	3
reseach institutes						
regional	Leibniz-Institute/ HKI e.V.	10	Technical University Imenau	6	Thuringia Inst. For Textile Reseach	5
national	Fraunhofer Gesellschaft e.V.	50	Heidelberg University	3	University of Applied Science Jena	2
international	no international reseach institue with more than 1 cooperation					

Table 3: Jena University's Cooperation Partners in Business and Research

Source: OECD (2016), EPO (2016), SCOPUS (2016). Author´s illustration.

Examining the cooperating research institutes on the regional level, Leibniz-Institute (HKI e.V.) is the most important research partner with 10 joint patent applications. Followed by the Technical University Ilmenau with 6 joint applications and Thuringia Institute for Textile Research with 5 joint patent applications. On the national level, as its headquarters are in Munich, the Fraunhofer Gesellschaft stands out with 50 joint patent applications. Followed by Heidelberg University with 3 joint applications and the University of Applied Science Jena (Hochschule Jena) with 2 joint patent applications. On the international level, there are no institutes that cooperate in the case of more than one joint patent application.

Cooperation predominately takes places with regional actors. This goes in line with the findings in the examined literature; in particular, with Fritsch and Slavtchev (2007) who detected with German patent data a major impact of a university in a 50-kilometer radius around it. In setting up and defining the Jena region for this thesis, the 50-kilometer radius determination was followed. For that reason, it is worthwhile to point out that in this thesis very similar result have been found in the patent data analysis. In the case of cooperating partners outside the Jena region two distinct circumstances have been found: First, for some partners outside the region a strong connection to Jena region has been identified. This is due to that they are either associated companies of a regional partner (e.g. Occultech Holding in Switzerland and Occultech GmbH in Jena) or they belong to the same concern (Schott AG is part of Carl Zeiss group located in Jena). This shows that even if a research partner is not located in Jena region, bonds exist that are directed to the region. Second, those partners outside Jena region that do not have any connection with the region, are mainly big companies (e.g. Bosch GmbH and Siemens AG) with a huge number of patents.

6.2. Regional Linkages

The following will analyse the connection between Jena University and its regional partners in more detail by going beyond the patent cooperation and also taking into account factors such as funded research and joint projects. The purpose of this is to reveal potential channels through which knowledge is transferred, but also to illustrate out of what kinds of cooperation and research potential patent collaboration can emerge. First, the relationship between Jena University and three regional private enterprises will be examined. Afterwards, the relationship between Jena University and regional partners in research will be surveyed with special attention given to the agglomeration of research institutes at Beutenberg Campus.

Cooperation with Regional Private Enterprises

Alere Technologies GmbH, which has been founded as **Clondiag GmbH** in Jena in 1998, is a globally acting enterprise and specialized in the development and production of innovative diagnostic testing systems and medical products and appliances (Alere Technologes GmbH, 2016). They cooperate in research matters among others with the Jena School for Microbial Communication at Jena University and the Abbe Center of Photonics also based at Jena University. An extensive collaboration between Jena University and Alere Technologies GmbH takes place in a project called InfectoGnostics research campus located in Jena and is funded until 2019 by the German Federal Ministry for Education and Research (InfectGnostics, 2016). The aim of this project is to provide scientists with a space where they can search for and test quick and cheap at-the-spot-solutions for infection analysis. 22 joint patent applications have been identified with the former name Clondiag GmbH.

Carl-Zeiss Foundation is related to Jena University in various ways. The foundation is the sole owner of Carl Zeiss AG and Schott AG, which are divided into several associated companies that also cooperate with Jena University. Just between 2007 and 2013 the Carl-Zeiss Foundation provided about 10 mil Euro for various research and teaching projects at Jena University (Carl Zeiss Foundation, 2016). In 2014 a new Centre of Excellence in Energy and Environmental Chemistry has been established and supported by the foundation with about 4 mil Euro. Moreover, the foundation finances the endowed chair for bioinformatics and high-throughput screening at Jena University (ZA Jena, 2016). Besides the financial support of the Carl-Zeiss Foundation, there is a huge number of research cooperation between the Jena University and the several companies associated with Carl-Zeiss Foundation. The Carl Zeiss Meditec AG is one of these companies and in terms of joint patent applications the overall second most important partner and the most important partner in the business world. 46 joint patent applications in the fields of optics, medical science and measuring/testing have been identified. The company is specialised in medical appliances with a focus on operational microscopy, medical laser and intraocular lenses (Carl Zeiss Meditec AG, 2016). The Carl-

Zeiss Jena GmbH is specialized in optical and photographic instruments and appliances, which are applied in the area of photonics as well as machine engineering or manufacturing (Carl Zeiss Jena GmbH, 2016). 10 joint patent applications with Jena University in the technological fields of optics and measuring have been classified.

Jenoptik AG is a Jena-based multi-cooperate enterprise that operates in more than 80 countries. Its focus is on optical technologies for enterprises working in engineering, medical measuring technics, aviation or semiconductor industries (Jenoptik, 2016). At Jena University the faculty for physics and astronomy is closely linked to the company. Jenoptik AG provides PhD scholarships as well as joint events and conferences. Lately, in cooperation with the Institute for Optics and Quantum Electronics (IOQ) at Jena University a pulse laser system has been developed that achieves pulse rates at world-class level. Within this cooperation not only Jenaoptik AG benefits from new insights, but also the cooperating companies Lastronics GmbH and Layertech GmbH. In total 12 joint patent application have been identified with various associated companies of the Jenoptik Group.

Cooperation with regional research institutes

Jena University is linked to many regional research institutes through joint research project and events. On the regional level the Leibniz Institute for Natural Product Research and Infection Biology is the most important cooperating partner in terms of joint patent applications. The institute dedicates its research to how micro-organisms produce both, pathogenic substances and pharmacological relevant components (Leibniz Institute, 2016). Besides that, also for the Technical University Ilmenau and the Thuringia Institute for Textile and Plastics Research 5 joint patent applications have been identified.

The interconnection and networking between companies and research institutes as well as the Jena University was to be fostered by establishing a technology and research campus named Beutenberg Campus located in the heart of Jena. On campus many research institutes are located, but also two incubators and more than 50 companies with biotechnological focus. In total about 3,000 people are employed, working and doing research primarily in the fields of bio-science and physics. Among other research institutes on the campus a Fraunhofer Institute, two Max-Planck Institutes and nine Institutes of the Leibniz Group are located (Beutenberg Campus, 2016). A selection of these institutes can be found on the illustrated map below. The green circles imply the location of an institute of Jena University and the red circles imply a location of a research institute.

Figure 6: Allocation of Research Institutes at Beutenberg Campus Jena

Source: OpenStreetMap (2016), Beutenberg Campus (2016). Author´s illustration.

1. Jena University - Institute for Applied Physics	8. Fraunhofer-Institute for Applied Optics and Fine Mechanics
2. Jena University - Center for Molecular Biomedical/ University Clinic Jena - Institute for Virology and Antiviral Therapy	9. Center for Innovation Competences Septomics
3. Max-Planck-Institute for Biochemistry	10. Abbe-Center Beutenberg
4. Max-Planck-Institute for Chemical Ecology	11. BioCentiv GmbH - Center for Bioinstruments
5. Institute for Photonic Technologies	12. Leibniz-Institute for Research into Ageing - Fritz-Lipmann-Institute
6. Wacker Biotech GmbH	13. Leibniz-Institute for Natural Product Research and Infection Biology - Hans Knöll Institute
7. Technology and Innovation Park Jena	

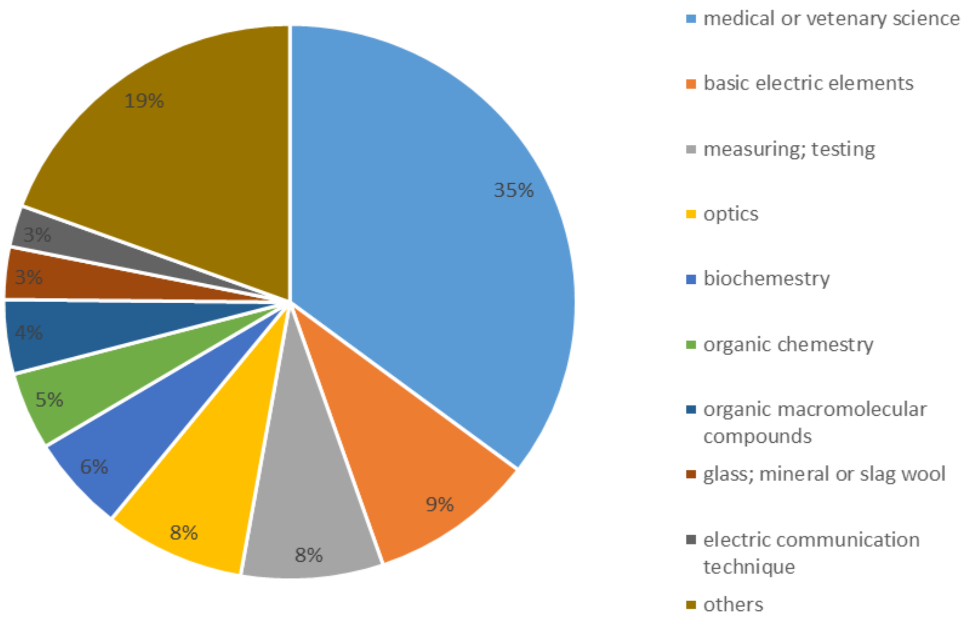
Linked research in terms of joint patent applications has been identified for also some of the institutes located at Beutenberg Campus. 50 joint patent applications have been identified with Fraunhofer Gesellschaft. The Fraunhofer Institute for Applied Optics and Fine Mechanics is located at Beutenberg Campus. As pointed out earlier, it was not possible to assign the patent application of Fraunhofer Gesellschaft to the individual institutes. However, at least some of these 50 patents have to be applied for with the local Fraunhofer Institute. This is also assumed due to the fact that the Fraunhofer Institute for Applied Optics and Fine Mechanics is among the collective of five research institutes and firms that finances the endowed chair “Theory of optic systems” at Jena University, which is linked to local clusters in optics and photonics. Besides joint patent applications with the Fraunhofer Gesellschaft, cooperation with the Leibniz Institute for Natural Product Research and Infection Biology, the Leibniz Institute for Research into Ageing and the Max-Planck Institute have been identified.

These findings indicate and give an insight that knowledge transfer between Jena University and its surrounding firms and research institutes takes place in more channels than only joint patent applications. However, due to the limitation of this thesis, these examples had the purpose to accentuate the role of Jena University in generating and transferring knowledge. Also, this was to illustrate through which kinds of cooperation and research potential patent collaboration can emerge.

6.3. Technology Fields

The identified 488 university-based patents that have been applied for with a partner can be classified into different technological fields. This has been done based on the International Patent Classification (IPC). The Word Intellectual Property Organization (WIPO) offers an online database that defines each IPC technology with subclasses (WIPO, 2016). For the subsequent analysis the first subclass has been used, which is indicated by the first three characters of the IPC class symbol (PATSTAT variable: ipc_class_symbol). Using the first subclass offers a degree of detail that is appropriate for this evaluation to analyse the main technology fields of joint patent applications; and therefore to examine the research areas that Jena University cooperates with other institutes and companies.

Figure 7: Joint Patent Applications as Classified by IPC Subclasses



Source: OECD (2016), EPO (2016), SCOPUS (2016). Author´s illustration.

Figure 7 shows the share of joint patent applications in the different technology areas as classified by the International Patent Classification (IPC) subclasses. By far the most patents of Jena University and its affiliated staff – more than one third – have been applied for in the field of *medical or veterinary science* (IPC code: A61). As the prior analysis of collaboration with private enterprises and research institutes revealed, this result is not surprising as most of joint patent applications took place with companies operating in the areas of medical appliances and biotechnologies. 9 percent of the joint patent applications can be assigned to the technological field of *basic electric elements* (IPC code: H01). Followed by *measuring; testing* (IPC code: G01) and *optics* (IPC code: G02). Also these classes reflect the areas that the cooperating companies are engaged in.

Comparing these findings with the research profile of Jena University and the technological focus of the regional firms and clusters, the identified technological fields reflect the research profile of Jena University and the regional clusters: medical science and optics. First, medical technology is one of the clusters in the Jena region with more than 1 billion Euro revenue in the city of Jena alone. But not only in the business world, but also in research medical science plays an important role. Two Leibnitz-Institutes, a Max-Plank as well as a Helmholtz Institute and the Jena University Clinic are engaged in the research fields of infection research, microbiology and medical science. Research focussing on these issues is organized under the umbrella of the research area "Life" at Jena University. Taking together the patents in the IPC subclasses of medical science, biochemistry and organic chemistry, this research area accounts for nearly half of the identified patents. Second, optics and photonics is another important cluster in the Jena region with global-players like Zeiss Jena GmbH and Jenoptic AG being two of the largest employers in the region. Jena University unites this area of research with interdisciplinary research in innovative materials and energy storage under the roof of "Light". Taking together the patents of the IPC subclasses of optics and glass, this research area accounts for the second most patents.

With these findings in mind, one calls back the idea of Brenner and Schlump (2013) who argue that the relationship between universities and their surrounding economy is not of a mono-directional kind. As the outlined findings suggest and also agreeing with Brenner and Schlump (2013), not only universities have an impact on the regional economy, but also the regional firms or the regional economy as a whole has an impact on the university and the research that is conducted at least in a technological direction.

6.4. Jena University – An Entrepreneurial University?

From the patent data analysis, it becomes noticeable that a considerable amount of cooperation takes place between Jena University and its spin-offs or companies that have been founded with the help and advice of university staff. In the following the relationship between Jena University and some of its spin-offs shall be outlined and the role of Jena University as an entrepreneurial university discussed.

SIRS-Lab GmbH is a company that develops molecular diagnostics methods and testing systems for life-threatening infections like sepsis. It has been founded as a spin-off of Jena University at the Jena Sepsis Competence Center by a team of researchers that aimed to combat the high mortality rate associated with sepsis. Among the founders of this spin-off were such well-known scientists as Prof. Dr. Konrad Reinhart, Director of the Clinic for Anestesiology and Intensive Medicine, Prof. Dr. Eberhard Straube, former Director of the Institute for Medical Microbiology at Jena University, and Prof. Dr. Hanspeter Saluz, Head of the Cell and Molecular Biology department at the Hans-Knöll-Institute in Jena. One of their first products was LOOXSTER, which has been a patented technology for concentrating bacterial and fungal DNA in diagnostic samples (Analytik Jena, 2013). 17 joint patent application in the fields of microbiology and medical science have been identified. In 2013, SIRS-Lab GmbH went insolvent and has been taken over by **Analytik Jena AG**. The company, which is specialized in instruments and products for life science, optical electrics and measuring appliances, collaborates with Jena University at the Center of Photonics and at the faculty of chemistry and geoscience. Moreover, the company finances an endowed chair in fibre optics in cooperation with the Foundation for technology, innovation and research Thuringia (Jena University, 2012). 4 joint patent applications have been identified.

JenaVale Technology Inc. is the US-based off-shoot of JenaVale Technology GmbH that has been founded in 2006 as a spin-off of Jena University. Prof. Dr. Hans-Reiner Figulla and Prof. Dr. Dr. Markus Ferrari, both cardiologists at the Jena University Clinic acted as idea generators for this company. On base of a new generation of trans-catheter aortic valve replacement (TAVR) systems for trans-apical and trans-femoral implantations this firm has been founded (JenaVale Technology, 2016). 8 joint patent applications in the field of medical science have been identified.

Occultech GmbH was founded in Germany in 2003 and is one of the leading companies in the field of structural cordial diseases. Also in the case of this company, Prof. Hans-Reiner Figulla has been idea generator, who was asked for help in developing a new generation of occluders. The aim was to reduce the amount of material that had to be implanted as well as to increase the flexibility in the case of atrial septal defects. Since then the company expanded significantly and among other associated companies the Occultech Holing in Switzerland has been founded (Occultech, 2012). Ocultech GmbH and the Swiss offshoot Occultech Holding worked together with Jena University in 14 joint patent applications in the field of medical science.

As pointed out earlier, the promotion of entrepreneurship is an increasingly important activity of universities. The main focus here is the creation of new firms, spin-offs and the economic exploitation of research knowledge (Porter, 2007). The findings show that Jena University acts as promoter of new business founding and cooperation while reacting to regional needs and demand. These needs are met by establishing new, innovative firms in the core technological fields of the regional economy, here mainly medical science. However, it is not just Jena University with the office for entrepreneurship "K1-Gründerservice" as an institution that fosters entrepreneurial activity, this spin-off mechanism also seems to be rather personalized – at least that is what the findings suggest to a certain degree. This is argued due to the fact that obviously some individuals play an essential role in acting as founder and advisor for new businesses. Prof. Figullla is one of these central actors as he was involved in a large number of spin-offs. Besides that, when cooperating with a spin-off, Jena University including its affiliated staff is the research partner with whom the majority of patents have been applied for. For that reason, it is argued that Jena University plays an essential role in transferring knowledge and skills to these enterprises. Overall, the number of examined firms is rather low, for that reason it is difficult to give a precise picture. Nevertheless, clear tendencies can be identified. Therefore, it is argued that Jena University and its scientists not only contribute to the regional economy with their work in teaching and research, but also by starting new businesses and promoting entrepreneurship. Moreover, it is emphasized in line with Audretsch and Keilbach (2004) that Jena University is recognized as a driver for economic growth, as well as increasing competition and contributing to economic diversity by fostering entrepreneurship.

7. Conclusion

7.1. Summary

The aim of this thesis is to analyse and quantify the economic effect of Jena University´s teaching and research activities on the regional economy. The examined literature on this issue provides strong evidence for an economic effect of universities on their surrounding regional economy in mechanism such as knowledge transfer and supply of human capital. However, these effects are of manifold kind and details are less studied. Therefore, this thesis combines macro- and micro-economic perspective in order to give a comprehensive analysis of the economic effect of Jena University on the regional economy. Moreover, this thesis not just accounts for and quantifies the overall macro-economic effect, but also reveals and illustrates exemplarily how the effect emerges on the micro-level. By doing so, patent networks and joint patents act as proxy for the economic impact of Jena University. These networks represent conduits for knowledge capital generated at Jena University.

The combination of the two methodological approaches has shown to be beneficial in order to quantify the macro-economic impact and underline it with micro-economic evidence. While with the help of the production function approach, the knowledge capital stock generated at Jena University and its regional effect in terms of human and research capital flows have been calculated; the patterns of knowledge transfer and cooperation have been analysed with the help of a patent data analysis guided by an approach introduced by Fraunhofer Institute for Systems and Innovation Research to identify not only university-owned, but also university-invented patents.

This thesis and its findings reveal that Jena University has an economic effect on the regional economy and its firms in terms of knowledge creation and transfer, but also in terms of the effects from human and research capital generated at Jena University. When quantifying the macro-economic effect of Jena University on the region, it is revealed that an effect of 459.9 mil Euro in terms of knowledge capital is operative in the Jena region in 2013, which corresponds to 1.2 percent of Jena region´s domestic product. The following findings on the micro-level underline the economic impact of Jena University on the regional economy:
First, research cooperation in terms of joint patent applications predominately takes place with a regional partner. 60 percent of the research partners are located within a 50-kilometers range around Jena University. Those partners outside the region are either associated companies of firms based in the Jena region or large companies and important players in their

industry. *Second*, the technological fields of cooperation that have been identified reflect the Jena region´s technological endowment and clusters as well as Jena University´s interdisciplinary research areas “Light” and “Life”. Therefore, it is argued that not only Jena University has an impact on the regional economy, but also the regional firms or the regional economy as a whole has an impact on Jena University and the research that is conducted, at least in a technological direction. *Third*, Jena University acts as promoter of new business founding and cooperation while reacting to regional needs and demand. While Jena University as an institution fosters entrepreneurial activity, this spin-off mechanism is also personalized to a certain degree. This is argued due to the fact that some individuals play an essential role in acting as founder and advisor for new businesses. Besides that, in cooperation with spin-offs, Jena University represents the most important research partner with whom the majority of patents is applied for. For that reason, it is argued that Jena University plays an essential role in transferring knowledge and skills to new enterprises and spin-offs.

7.2. Limitation of the Study and Further Research

Despite the fact that this thesis has been carefully prepared and accomplished its purpose, there are limitations and shortcoming that shall be raised in the following. Generally, this thesis focuses on the economic effect generated by Jena University´s teaching and research activities only. Economic demand effects created by students or employees have been blanked out. Also any impact of factors coming from outside the Jena region such as migration inflows has been left aside. These factors could have been taken into account for an even more elaborate analysis, however, this would have exceeded the aim of this thesis.

Another limitation is that the calculation of the knowledge capital stock is based on a large number of assumptions. Although they are all carefully chosen in accordance with earlier studies on this issue, the findings imply a degree of uncertainty. As pointed out earlier, the applied parameters are up for discussion as in most cases a fairly wide range of each parameter was found in the relevant literature. Therefore, these estimations can only be seen as an illustration, though, they give an idea of the economic effect and the importance of Jena University for the regional economy. For that reason, further research should focus on improving the determination of the parameters applied in the knowledge capital stock estimation. Apart from that, as only data from 2000 onwards has been available, it had to be made use of an initial stock. This adds another factor of uncertainty.

Concerning the patent data analysis, also some limitations have to be outlined. First of all, despite the fact that the selection criteria for the matching process have been determined cautiously, the number of patents might still be underestimated. The issue here is to find the right balance between criteria that is too narrow and criteria that is too wide, which would result in an overestimation of academic patents. In particular defining the point in time, which shall be matched appeared to be rather difficult. Apart from that, another selection criterion to specify the matching process could have been the field of research or publication. Moreover, for this thesis it has been chosen to analyze patents applied for at the EPO due to potentially higher commercial value. However, a significant share of academic patents in Germany is applied for only at the German Patent Office. Therefore, an analysis of those patents might have revealed a different picture.

7.3. Concluding Remarks

As this is a case study of Jena University and the surrounding regional economy, generalizing from these findings has to be cautious. Nevertheless, the empirical findings from both, the macro- and the micro-level allow generalization to a certain degree. In line with the literature on the economic impact of universities, it is argued that in general universities play an important role in regional economies. This is due to their teaching and research activities, which lead to research and human capital creation. However, the degree of regionalization of these capital flows differs from region to region depending on factors like graduate mobility and general economic endowment of a region. Still, the macro-economic effect exists and can be quantified, although parameters are difficult to determine and may differ. On the micro-level universities have an economic effect as they act as generators of knowledge and human capital – not because of economic interest, but because it has been their raison d'être ever since.

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Appendices

Appendix A

Glossary and abbreviation

Jena Region The following NUTS3-regions are defined as Jena region: *DEE08: Burgenland Kreis, DEG02: Gera (city), DEG03: Jena (city), DEG05: Weimar (city), DEG0D: Sömmerda, DEG0F: Ilm-Kreis, DEG0G: Weimar (administrative district), DEG0I: Saalfeld-Rudofstadt, DEG0J: Saale-Holzland-Kreis, DEG0K: Saale-Orla-Kreis, DEG0L: Greiz, DEG0M: Altenburger Land*

EPO European Patent Office

Fraunhofer ISI Fraunhofer Institute for Systems and Inno vation Research, Karlsruhe

IPC International Patent Classification

NUTS3 Nomenclature des unités territoriales statistiques, regional disctrict corresponding to administrative district level

PATSTAT EPO Worldwide Patent Statistical Database

REGPAT OCED rationalized patent database

R&D Research and Development

WIPO World Intellectual Property Organization

Appendix B

I. Expenditures in Research and Training at Jena University

year	state funding	state funding	state funding	external fundin	sum teaching	sum reserach
	total, in €	training, in €	research, in €	reserach, in €	in €	in €
2000	115,745,217	75,234,391	40,510,826	29,358,959	64,780,223	60,161,054
2001	123,431,012	80,230,158	43,200,854	26,678,620	69,772,346	60,770,850
2002	119,906,074	77,938,948	41,967,126	31,898,752	68,737,601	65,145,391
2003	121,657,891	79,077,629	42,580,262	28,458,265	70,515,709	63,347,019
2004	120,726,469	78,472,205	42,254,264	29,013,063	71,053,361	64,529,640
2005	123,440,766	80,236,498	43,204,268	30,872,897	72,979,053	67,376,836
2006	124,437,322	80,884,259	43,553,063	34,765,740	73,669,459	71,332,838
2007	120,561,344	78,364,874	42,196,470	45,238,988	72,453,695	80,840,072
2008	131,210,625	85,286,906	45,923,719	48,407,757	79,678,928	88,128,778
2009	145,781,551	94,758,008	51,023,543	53,324,644	89,519,886	98,579,930
2010	154,469,079	100,404,901	54,064,178	60,498,166	95,976,519	109,509,544
2011	176,312,517	114,603,136	61,709,381	64,674,777	110,823,880	122,216,400
2012	177,045,390	115,079,504	61,965,887	66,864,476	112,684,167	126,148,807
2013	182,786,628	118,811,308	63,975,320	75,289,510	118,811,308	139,264,830

II. Research and Human Capital Stock at Jena University

year	Deflator	sum t+r	stock (training)	stock (research	**sum stock (t+r)**
	Index 2013	in €	in €	in €	in €
2000	0.86	124,941,277	1,267,369,835	282,589,198	**1,549,959,032**
2001	0.87	130,543,196	1,324,468,483	300,971,668	**1,625,440,151**
2002	0.88	133,882,993	1,379,961,399	320,971,309	**1,700,932,708**
2003	0.89	133,862,728	1,436,677,495	336,172,632	**1,772,850,126**
2004	0.91	135,583,001	1,493,364,081	350,276,377	**1,843,640,458**
2005	0.91	140,355,890	1,551,409,493	365,111,757	**1,916,521,250**
2006	0.91	145,002,297	1,609,564,857	381,677,831	**1,991,242,689**
2007	0.92	153,293,767	1,665,922,904	405,266,229	**2,071,189,132**
2008	0.93	167,807,706	1,728,942,603	432,605,073	**2,161,547,675**
2009	0.94	188,099,816	1,801,173,063	466,294,242	**2,267,467,305**
2010	0.96	205,486,062	1,879,137,851	505,859,649	**2,384,997,500**
2011	0.97	233,040,280	1,971,170,353	552,197,102	**2,523,367,454**
2012	0.98	238,832,973	2,064,142,816	595,516,343	**2,659,659,159**
2013	1.00	258,076,138	2,162,312,696	645,453,722	**2,807,766,417**

III. Effect of Research and Human Capital Stock on Regional and Transregional Level

year	share research regional, in Euro	share training regional, in Euro	sum (region) regional, in Euro	share research transregional, in Eur	share training transregional, in Eur	sum (transregional transregional, in Eu
2000	168,423,162	416,964,676	585,387,837	90,711,132	790,838,777	881,549,909
2001	179,379,114	435,750,131	615,129,245	96,611,905	826,468,333	923,080,239
2002	191,298,900	454,007,300	645,306,200	103,031,790	861,095,913	964,127,703
2003	200,358,888	472,666,896	673,025,784	107,911,415	896,486,757	1,004,398,171
2004	208,764,721	491,316,783	700,081,503	112,438,717	931,859,187	1,044,297,904
2005	217,606,607	510,413,723	728,020,330	117,200,874	968,079,524	1,085,280,398
2006	227,479,988	529,546,838	757,026,826	122,518,584	1,004,368,471	1,126,887,055
2007	241,538,672	548,088,635	789,627,307	130,090,459	1,039,535,892	1,169,626,351
2008	257,832,623	568,822,116	826,654,740	138,866,228	1,078,860,184	1,217,726,412
2009	277,911,368	592,585,938	870,497,306	149,680,452	1,123,931,991	1,273,612,443
2010	301,492,351	618,236,353	919,728,704	162,380,947	1,172,582,019	1,334,962,966
2011	329,109,473	648,515,046	977,624,519	177,255,270	1,230,010,300	1,407,265,570
2012	354,927,741	679,102,986	1,034,030,727	191,160,746	1,288,025,117	1,479,185,863
2013	384,690,418	711,400,877	1,096,091,295	207,190,645	1,349,283,122	1,556,473,767

IV. Growth Effects at Different Geographical Levels

growth effects due to ...	regional	transregional	Germany	international
reserach capital	150,746,175	81,190,474	231,936,649	20,993,175
human capital	309,118,177	586,291,010	895,409,186	44,159,740
knowledge capital	459,864,352	667,481,483	1,127,345,835	65,152,915

V. Parameters for Knowledge Capital Stock Estimation

deprecitation rate reserach capital	0.15
depreciation human capital	0.01
marginal productivity of knowledge capital	0.5
operational lag (years)	3
regional share of effect (training)	0.329
regional share of effect (research)	0.596
transregional share of effect (training)	0.624
transregional share of effect (research)	0.321
international share of effect (training)	0.047
international share of effect (research)	0.083

Appendix C

Structure of the Relational Database

First and foremost, the relational database has been set up. Due to availability only four tables of the PATSTAT database have been set up. For an extended list of columns and information in each table see appendix (XX):

TLS201_APPLN, which includes information on application authority, application and filing date as well as the international patent family number.

TLS207_PERS_APPLN, which acts as the connecting element between TLS201_APPLN and TLS206_Person. Among other information, it consists of connecting variables *appln_id* and *person_id*.

TLS206_PERSON, which contains information on the applicant name, address and country.

TLS209_APPLN_IPC, which contains information on the actual innovation by revealing details about the technology in the International Patent Classification (IPC).

In order to analyse the geographical dimension of the university´s patenting activities and cooperation, the relational database has been extended by tables taken from REGPAT database. This allows to locate innovators, which is essential to match patent data with data from SCOPUS database, but also to examine the special distribution of cooperating research institutions and private enterprises.

Due to availability the following three tables have been set up:

201602_EPO_App_reg, which contains information on the applicant as well as the connecting variables *appln_id* and *person_id*

201602_EPO_Inv_reg, which contains information on the inventor as well as the connecting variables *appln_id* and *person_id*

201602_EPO_IPC, which contains information on the IPC as well as the connecting variables *appln_id* and *person_id*

Appendix D

List of University-based Patents of Jena University and the University Clinic Jena

EPO ID	Applicants	Appl. ID
EP19990124598	Hermsdorfer Institut für Technische Keramik e.V.	17393376
EP19990961974	Friedrich-Schiller-Universität Jena; Cybio Screening GmbH	17452955
EP19990964464	Friedrich-Schiller-Universität Jena; Id Pharma GmbH; Presselt, Norbert	17454527
EP20000108913	Friedrich-Schiller-Universität Jena	15713921
EP20000116159	Friedrich-Schiller-Universität Jena; Wolff Walsrode AG	15719933
EP20000116181	Friedrich-Schiller-Universität Jena; Wolff Walsrode AG	15719947
EP20000126133	Borealis GmbH	15728016
EP20000914033	Jenapharm GmbH & Co. KG	15759429
EP20000934997	3di GmbH	15769562
EP20000942026	CARL ZEISS JENA GmbH	15773509
EP20000953039	FITR Gesellschaft für Innovation im Tief- und Rohrleitungsbau Weimar m.b.H.	15779608
EP20000954464	CARL ZEISS JENA GmbH	15780386
EP20000979394	Alceru Schwarza GmbH	15793405
EP20000979396	Alceru Schwarza GmbH	15793406
EP20000979466	Biomedical Apherese Systeme GmbH	15793454
EP20000981147	Alceru Schwarza GmbH	15794382
EP20000990664	Intron Jena Gesellschaft für Digitale Farbtransfer Drucktechnik mbH	15799501
EP20010102423	Agfa-Gevaert AG	15803759
EP20010102829	Merck Patent GmbH	15804093
EP20010104398	SIRS-Lab GmbH	15805367
EP20010113396	SIRS-Lab GmbH	15812753
EP20010115946	SIRS-Lab GmbH	15814834
EP20010119041	Siemens AG	15817284
EP20010120844	Vistec Electron Beam GmbH	15818689
EP20010126862	Little Things Factory GmbH	15823323
EP20010129137	SIRS-Lab GmbH	15825109
EP20010129239	Bita GmbH, Niederlassung Thüringen	15825187
EP20010270624	Institut für Physikalische Hochtechnologie e.V.;	15830452
EP20010903766	Jenpolymers Ltd.	15850821
EP20010911390	Bolta-Werke GmbH	15854736
EP20010913516	Thüringisches Institut für Textil- und Kunststoff-Forschung e.V.	15855816
EP20010916903	JenaValve Technology Inc.	217043
EP20010929231	JenaValve Technology Inc.	15863819
EP20010940177	Depuy Biotech Jena GmbH	15869375
EP20010943135	Dyomics GmbH	15870956
EP20010943441	Sunyx Surface Nanotechnologies GmbH	15871159
EP20010945128	Fraunhofer Gesellschaft zur Förderung der angewandten Forschung e.V.	15872002
EP20010949465	3di GmbH	15874363
EP20010955359	Bundesdruckerei GmbH; Orga Kartensysteme GmbH	15877207
EP20010960099	Fraunhofer Gesellschaft zur Förderung der angewandten Forschung e.V.	15879498
EP20010960319	Curacyte AG	15879644
EP20010964989	Curacyte AG	15881899
EP20010965073	CARL ZEISS JENA GmbH	15881959
EP20010974230	Friedrich-Schiller-Universität Jena	15886027
EP20010978165	Friedrich-Schiller-Universität Jena	15887770
EP20010982167	Schering AG	15889694
EP20010983522	CARL ZEISS JENA GmbH	15890391
EP20010985659	Schering Aktiengesellschaft	15891497
EP20010986583	Forschungszentrum Karlsruhe GmbH	15891942
EP20010987609	Robert Bosch GmbH	15892444
EP20010987663	WPMO GmbH	201811
EP20010990410	Fraunhofer Gesellschaft zur Förderung der angewandten Forschung e.V.	15893846
EP20010995576	Fraunhofer Gesellschaft zur Förderung der angewandten Forschung e.V.	15896468
EP20010998642	MediGene Aktiengesellschaft	15898120
EP20020004978	Heraeus Kulzer GmbH	15902715

EP20020005023	Heraeus Kulzer GmbH	15902752
EP20020005024	Heraeus Kulzer GmbH	15902753
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EP20100013830	F.HOFFMANN-LA ROCHE AG; Roche Diagnostics GmbH	328524148
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