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Venture Capital in Germany and the United Kingdom: A Focus on the Life Sciences Industry

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Academic literature suggests that a stock market-centered financial system, such as in the United Kingdom, promotes a strong and dynamic venture capital market in a better way than a bank-centered financial system, like in Germany, permitting venture capitalists to exit more successfully from their investment through an IPO. This hypothesis is investigated by comparing private equity and venture capital funding in both countries with an emphasis on the life sciences industry. For this purpose time series data from 2002 to 2012, including the financial crisis of 2007/2008 and its aftermath, are analyzed using econometric time series models especially of the ARIMA class. The results demonstrate that the British private equity market, both in total and for life sciences companies, is significantly bigger than its German correlate during these years. However, the differences between both countries disappear when looking at venture capital for early stage financing. Furthermore, it can be shown that life sciences are a more important investment target for private equity and venture capital in Germany than in the United Kingdom. Another result and further distinction between the two countries is the vulnerability to the financial crisis of 2007/2008. While this event has a clearly negative influence on the British market, especially on early stage venture capital, in the years following the initial event, the German equivalent hardly suffers from its impact. Overall, the outcome of the study doesn't support the view that a market-centered financial system quasi automatically ensures a bigger market for all forms of venture capital at any time.

Field of Research: Corporate Finance, Entrepreneurial Finance, Financial Markets, Life Sciences Industry, Private Equity, Venture Capital.

1. Introduction

Getting a start-up company off the ground is only possible if the necessary financial resources can be obtained (Blanchflower & Oswald 1998). Financing start-ups, however, differs from financing "normal" companies. A start-up in its early business stages typically generates no profits or, sometimes, no returns at all from its regular business activities. This is why there are few opportunities for self-financing in this phase of business' development. Similarly, write-offs and accrued liabilities are not yet considered to be significant financing sources too. The preferred source of funding based on the pecking order theory (Myers & Majluf 1984; Myers 2001) is internal (self-)financing and, for the above mentioned reasons, this is usually not available in the case of new ventures. Therefore, new companies have to rely on outside sources for funding. In addition to the financial resources provided by the company's founders themselves, capital is often achieved by standard debt financing through a traditional bank loan (Berger & Udell 1998). The other alternative would be equity financing by offering company shares to venture capital companies or private "angel" investors. Once again specific peculiarities of start-up financing referring to the availability and choice of different financing instruments normally lead to different results compared to the statements made by

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the established capital structure theories (for an overview see e.g. Harris & Raviv 1991; Zwiebel 1996; Myers 2001; Knockaert et al. 2010). As a rule, start-ups are not able to choose between equity partnerships, such as venture capital, or bank loans for external financing. Instead their options tend to be limited to one of these financial instruments depending on the nature of the start-up project and its industry.

Venture capital, in particular, is not always available for every stage of every start-up process. At present most formal venture capital funds primarily focus on innovative projects in technology-based sectors (Hogan & Hutson 2007). Moreover, only a small part of such funding goes to finance early phases of a project, i.e. seed and start-up financing (Murray 1999). Due to their significantly lower financing volumes, business angels, however, are in principle more suited to improve the capital base of recently formed start-ups. But even here investments tend to lay emphasis on innovative growth industries. So, both forms of venture capital, formal by venture capital funds and informal by business angels, generally favor start-up projects with high growth and high profits. On the other hand, this type of new companies is also marked by high risks and rather little collaterals (Berger & Udell 1998; Gompers & Lerner 2001; Ueda 2004; Huyghebaert & Van de Gucht 2007; Winton & Yerramilli 2008).

One important sector characterized by innovative, high tech companies and start-ups is the life sciences industry. It is widely seen as a significant driver of future innovation and economic growth generating employment and income (Gertler & Vinodrai 2009). The business activities in this branch typically call for significant equity investments and have a delayed payback (Champenois, Engel & Heneric 2006; Bastin et al. 2007). Hence, it doesn't come as a surprise that venture capital plays an important role as financial resource for this sector. The following article, therefore, wants to look at the use of private equity and venture capital in the life sciences industry. Simultaneously there is a second special focus on venture capital provided for early stage financing of new companies in this sector. For that purpose the two most important markets for private equity and venture capital in Europe, Germany and the United Kingdom (UK) (Mayer, Schoors & Yafeh 2005; Haeussler & Colyvas 2011), are to be analyzed and compared in a longitudinal study from 2002 to 2012 using the statistical data of the corresponding national venture capital associations. In doing so a comparison can be drawn between a bank-centered financial system as Germany and the traditionally stock market-centered British system (Haeussler 2011; Belussi & Sedita 2015). Additionally, this study is limited to formal capital, because financing by business angels represents a typical informal market. Although some research on business angels and their activities can be found in the literature (KfW-Bankengruppe 2011; Mason & Botelho 2014), up to now the necessary information and the required data are not available to compare accurately enough the activities of business angels and their financial investments in both countries.

Concretely, this paper is structured as follows: The next section gives a short literature review addressing previous research on venture capital markets in Germany and the UK. In a following step, some clarification is made about the conceptual fundamentals and the data bases used in this article. Afterwards the empirical work and its results are presented in the subsequent two sections 4 and 5. The issue of this analysis lies on comparing private equity and venture capital in Germany and the UK. In this regard two special focus areas are particularly investigated. These areas are early stage venture capital and investments into the life sciences industry. Section 4 introduces the time series of basic parameters in the German and British private equity and venture capital markets, while the following section 5 deals with the time series of some composed parameters, namely deal sizes and various

ratios. In doing so the statistical analysis reveals a few interesting results. First, it is demonstrated that the financial crisis in 2007/2008 affects private equity and venture capital in a stronger and more negative way in the UK than in Germany. Second, although the British private equity market as a whole is much bigger than its German counterpart and shows bigger deals, such differences disappear when looking at both the life sciences sector and early stage financing. The article ends with a short conclusion of the main outcomes.

2. Literature Review

Comparing private equity and/or venture capital between different countries, academic research has found some interesting divergences so far. There are countries renowned for a strong private equity/venture capital industry such as the United States and the United Kingdom. In contrast especially Japan and Germany are said to be at low levels in this case having a rather weak private equity/venture capital branch. In this context the literature identifies and discusses various issues to explain international divergences (for an overview e.g. Oehler et al. 2007; Schröder 2013).

Aside from cultural and institutional variations (Bruton, Fried & Manigart 2005), there is the tendency to consider the respective financial and capital market system a critical explanation for variations between different countries. Black and Gilson (1998) argue that a strong stock market is important to the existence of an also strong and dynamic venture capital market permitting venture capitalists to exit better from their investment through an IPO (initial public offering). The idea behind this reasoning relates to control rights. All special supervision rights given to the venture capital fund at the beginning of its investment diminish at the time of an IPO and afterwards. As the entrepreneur often retains a controlling shareholding, he could regain authority through the IPO exit, in particular if the company was successful. So, basically, the chance of an IPO gives the entrepreneur quasi a call option on future control contingent upon the company's success. However such type of implicit contract over future control rights depends on the availability of exit through an IPO. Because this link works only in the presence of a(n) (active) stock market, rather stock market-centered financial systems, like the UK, gain an advantage over rather bank-centered financial systems, like Germany (Black & Gilson 1998; Schröder 2013).

According to this theoretical framework, the British venture capital market should be bigger than its German counterpart. Previous empirical evidence is in line with this assumption for the venture capital and private equity industry at large (Oehler et al. 2007; Schröder 2013). But for the segment of early stage venture capital, the first focus of this article, there are no homogenous results and the related findings are mixed. On the one hand, some evidence (Schröder 2013) confirms the expectation that early stage funding takes place more likely in countries with stock market-centered capital markets (Bruton, Fried & Manigart 2005). On the other hand, other articles observe that the share of money allocated to seed capital and investment into the earliest stages of new companies remains small in the UK, for the lion's share of funding is concentrated on later stage deals particularly directed into financing management buy-outs/buy-ins (Murray 1999; Jeng & Wells 2000; Martin et al. 2003). Contrary to this British situation, the German venture capital market is reported to be more oriented to start-up and expansion financing (Martin et al. 2003; Heger, Fier & Murray 2005; Mayer, Schoors & Yafeh 2005).These latter results match empirical findings at international level that IPOs promote the private equity and venture capital market as a whole but hardly affect early stage investments (Jeng & Wells 2000).

A second focus area of this article lies on private equity and venture capital for the life sciences industries in the UK and Germany. Both countries host the most companies of this high tech sector in Europe (Haeussler 2011; Belussi & Sedita 2015). Until now there are only a few side notes in academic research for this topic. For example, Mayer, Schoors and Yafeh (2005) report that life sciences are an important investment issue for venture capital. But a deeper and more systematic analysis, in particular about recent trends over time, cannot be found in the relevant literature yet. Hence it is difficult to make any sound statements in advance. Considering the significance of the pharmaceutic sector and other life sciences branches for the entire German economy (Lehrer & Asakawa 2004; Belussi & Sedita 2015), it can, however, be expected that the discrepancies between both countries are getting smaller in this industry than in the aggregated private equity and venture capital market.

So far statistical time series analysis is also no big subject in the related research publications and mostly executed in a descriptive way (e.g. Murray 1999; Oehler et al. 2007; Schröder 2013). Connected to time series development, another issue to be investigated in this article is the effect of the financial crisis in 2007/2008 on private equity and venture capital. It can be expected for stock market-centered financial systems to be more prone to disruptions in (organized) capital markets than bank-centered financial systems. During these disturbances call options on future control through IPOs, as proposed in Black and Gilson's (1998) model, are reduced. Hence a stock market-centered financial system will (temporarily) lose its advantage in venture capital funding over a bank-centered financial system in such times. In summary, the financial crisis should have hit the UK market for private equity and venture capital harder than its German counterpart.

3. Data Bases and Conceptual Fundamentals

In both Germany and the UK, most private equity and venture capital companies or funds are organized in nationwide associations. In Germany this is the Bundesverband Deutscher Kapitalbeteiligungsgesellschaften – BVK, while its UK counterpart is named the British Private Equity and Venture Capital Association – BVCA. Providing comprehensive and representative information about private equity and venture capital investments in each country, their annual reports constitute the data bases for the following research. At the same time this article primarily looks at the industry statistics of the private equity and venture capital branches. As a consequence, in both countries its focus lies more on the finance companies analyzing their national or international funding and less on the life sciences industries themselves. For this purpose the annual statistics of BVK and BVCA from 2002 to 2012 are used to search for industry differences between Germany and the UK by calculating various time series and deduced parameters of venture capital investments.

Before presenting the empirical part of the paper, some clarifications are needed with regard to the conceptual base of two notions used here. These two concepts are venture capital together with the connected term early stage financing on the one hand and life sciences industry on the other hand.

Starting with venture capital and early stage financing, there is sometimes a kind of terminological fuzziness in the literature concerning both notions. In academic publications venture capital is often and typically defined as investments in seed, early stage, and expansion companies thus including normal expansion and bridge capital (e.g. Black & Gilson 1998; Beuselinck & Manigart 2007; Revest & Sapio 2012). A similar approach is used by the BVK (Bundesverband Deutscher Kapitalbeteiligungsgesellschaften 2007) referring to all

private equity investments except management buy-outs/buy-ins as venture capital. Occasionally the term venture capital market even embraces management buy-outs/buy-ins (Martin et al. 2003). Then again, the BVCA explicitly excludes expansion and bridge financing from its concept of venture capital (BVCA & PricewaterhouseCoopers 2010). Therefore to prevent any terminological vagueness, this article doesn't look at the standard academic definition of total venture capital including expansion and bridge funding. Instead the entire private equity market is studied covering also expansion and replacement capital together with financial investments in management buy-outs/buy-ins and additional forms of late stage financing.

As to the notion of early stage financing, the German BVK solely distinguishes between seed financing and start-up financing in its statistics, both together are labeled early stage financing (Bundesverband Deutscher Kapitalbeteiligungsgesellschaften 2007; Vincenti & Winters 2008). On the other hand, the reports of its British counterpart contain an additional stage just called early stage venture capital (e.g. BVCA & PricewaterhouseCoopers 2010). As a result, the statistical data of the BVCA show three different sources of total early stage financing, that is seed, start-up, and early stage venture capital. However, this classification cannot be uniformly maintained when early stage financing in the life sciences industry is to be analyzed. Only the BVK provides separate data for seed and start-up venture investments into this branch, whereas the BVCA solely presents aggregated data that contain not only the venture capital for its three stages of early stage financing, but also the capital expenditures for later stage venture capital in this sector. Hence, the British data, as they are used in this work to describe early stage financing in the life sciences industry, include all venture capital investments for this branch except expansion stage funding and other similar investments. In the end, these differences between the data sources for early stage venture capital in the life sciences sector lead to an overestimation of the capital expenditures and the companies this money has been invested in for the UK. Its numbers should have been less compared with Germany, had a uniform calculation base been possible.

Depending on the point of view, the second term life sciences industry includes different segments. From an academic angle, life sciences primarily embrace research in bio sciences, maybe supplemented by areas with noticeable overlaps to biological issues such as chemistry, biochemistry, or biophysics. Sometimes it is almost equal to the term biotechnology (Owen-Smith et al. 2002; Powell et al. 2002; Cooke 2004; Bastin et al. 2007). This point of view is also reflected in the thematic arrangement of academic journals used by scientific publishing houses, e.g. Wiley and Springer, and the structure of the course programs in life sciences offered by various universities.

However, this article is going to use an extended concept of life sciences including the areas of medicine and pharmacy, like it is common in business issues (see also e.g. Haeussler & Colyvas 2011; Henderson 2015). Such an enlarged terminology especially corresponds to the notions of life sciences respectively health care as these concepts are interpreted by private equity and venture capital associations. Both associations, BVK in Germany and BVCA in the UK, accordingly subsume the branches biotechnology, medical equipment, pharmacy, and health care under the category life sciences industry in their reports. Unfortunately, these terms and the associated classification are not executed strictly in each and every report. For example, life sciences are called health care in a recent BVCA report. Yet the fundamental structure of this sector remains mostly unaffected by such terminological inconsistencies. Overall and despite the just mentioned conceptual fuzziness, both terms life

sciences industry and venture capital can be seen as similar notions in both countries to be well compared (Lange 2009).

4. Basic Parameters of Private Equity and Venture Capital

As told before, the annual reports of the BVK and the BVCA provide the data for the following statistical research. All financial amounts are stated in million (MM) Euros (€). In this connection the money data from the UK, originally given in British pounds (GPB), are converted into € using the exchange rate of 1.25 € per 1 GBP from the 16th November 2014. 16 variables are extracted directly from the annual reports. First, these are the total sums of private equity investments per year made by German (t M GE) and UK (t M UK) private equity firms as well as the total numbers of companies per year this money was invested in (t Co GE and t Co UK). The equivalent 4 variables are given for early stage venture capital financed by German und UK firms, once again both for the amount of funding (e M GE and e M UK) and the numbers of the receiving companies (e Co GE and e Co UK). This data structure also holds for the values of private equity investments into the life sciences industries (ls M GE and ls M UK, ls Co GE and ls Co UK) and early stage investments into the same branch (els M GE and els M UK, els Co GE and els Co UK).

Table 1 presents the characteristics of the time series for all 16 basic variables. While column 1 names the model of each variable, column 2 shows the corresponding type of model. Please note that only ARIMA models are permitted and (exponential) smoothing models are principally deselected, because the latter doesn't allow for including independent variables (for ARIMA models see in detail e.g. Harvey 2006; Box et al. 2016). In this context every time series model used in this article considers the financial crisis in 2007/2008 as a potential additional variable (Crisis 09-12). It is included as a dummy variable assuming a delayed impact on financial investments from 2009 to 2012. Concerning model fit, column 3 presents the values of the normalized BIC (Bayesian Information Criterion) (Schwarz 1978; Burnham & Anderson 2004). All chosen types of ARIMA model are selected by minimizing this parameter. The following columns 4 and 5 give the relevant variables used for every basic model. In the last 3 columns 6 to 8 the respective model descriptions can be found. Especially the estimated values in column 6 and the standard error of the (arithmetic) sample mean in column 7 are of particular importance.

The detailed analysis of table 1 reveals that there are only two types of ARIMA models to describe the time series of all basic variables best. For most of them this can be done by applying an ARIMA (0,0,0) model. ARIMA (0,0,0) models are mean (or constant) models with only a constant term but no AR (Autoregressive) or MA (Moving Average) terms as well as no differencing. An ARIMA (0,0,0) model is simply equivalent to white noise and the most suitable forecast minimizing the mean squared error is the (arithmetic) mean of the sample. For example, the best estimated value E(ls M GE) for German private equity investments into the life sciences industries at the time t represents a constant c which equals the (arithmetic) sample mean. Hence, the expected value $\hat{E}(\text{ls M GE})_t$ of this variable consists of c plus an additional white noise term ε_t:

$$\hat{E}\left(\text{ls M GE}\right)_t = c + \varepsilon_t \text{ with } c = \sum_{t=2002}^{2002+n}\left(\text{ls M GE}\right)_t / n \text{ and } \varepsilon_t \sim WN\left(0, \sigma_\varepsilon^2\right).$$

Two basic parameters (t Co UK, e Co UK), however, show an ARIMA (0,1,0) model denoting a random walk model with first order differencing but without drift. Using this type of time

series model, the best estimation for a variable in period t is its value in the previous period t-1. The expected value, e.g. for the parameter (e Co UK), is given, therefore, as follows:

$$\hat{E}(\text{e Co UK})_t = (\text{e Co UK})_{t-1} + \varepsilon_t .$$

Because the table view of this type of time series doesn't disclose any details about the size of the included parameters, an additional ARIMA (0,0,0) model marked with an asterisk * is added to the table for every variable represented by an ARIMA (0,1,0) model.

In regard to its content, table 1 reveals the tendency that total private equity investments in terms of money are distinctly larger in the UK than in Germany. But the difference between both countries decreases when looking at (total) early stage venture capital and at private equity for the life sciences industry. For early stage investments in the life sciences sector, the gap even disappears completely especially as soon as the already described divergences in the data bases, causing a tendency to overestimate the British amounts of money, are taken into account. Any greater difference between the two countries also dissipates if the numbers of the receiving companies are analyzed instead of the amounts of money. These tendencies will later be studied more detailed by comparing associated ratios in table 5 and 6.

A second remarkable distinction between both markets refers to the impact of the financial crisis. It becomes apparent that the independent parameter Crisis 09-12 only induces a downward shift of the time series of some UK basic parameters (t Co UK, e M UK, e Co UK, ls Co UK, els M UK). Particularly British investments in early stage venture capital are severely reduced by it. From 2009 to 2012 the annual average of money spent for early stage financing (e M UK) sank from 740 MM €, which was the mean until 2008, to 363 MM € on average in the following years. These UK results broadly confirm the adverse consequences of this event found on international scale (Belussi & Sedita 2015). On the contrary, there are no signs for negative effects of the financial crisis on German private equity and venture capital activities. Instead the number of companies early stage venture capital was invested in (e Co GE) increased on average since 2009. All told and conform to previous considerations, the negative effects of the crisis are striking unilaterally the British private equity industry, which is embedded in a more stock market-centered system, much heavier than its German counterpart, which is associated with a more bank-centered system.

Table 1: Time series of basic parameters

Model	Type (ARIMA)	Model Fit (Normalized BIC)	Model Parameters		Estimate	Std. Error	Sig.
t M GE_1	(0,0,0)	15.037	t M GE	Constant	4115.925	497.885	.000
t M UK_2	(0,0,0)	18.585	t M UK	Constant	19393.636	2935.449	.000
t Co GE_3	(0,0,0)	11.253	t Co GE	Constant	1200.364	75.090	.000
t Co UK_4	(0,1,0)	8.361	t Co UK	Difference	1		
			Crisis 09-12	Numerator Lag 0	-696.000	58.300	.000
				Difference	1		
*t Co UK_4**	*(0,0,0)*	*9.074*	*t Co UK*	*Constant*	*1576.429*	*28.393*	*.000*
			Crisis 09-12	*Numerator Lag 0*	*-549.929*	*47.084*	*.000*
e M GE_5	(0,0,0)	9.167	e M GE	Constant	393.166	26.453	.000
e M UK_6	(0,0,0)	11.653	e M UK	Constant	740.000	103.110	.000
			Crisis 09-12	Numerator Lag 0	-376.563	170.989	.055
e Co GE_7	(0,0,0)	10.136	e Co GE	Constant	457.000	48.282	.000
			Crisis 09-12	Numerator Lag 0	178.000	80.066	.053
e Co UK_8	(0,1,0)	6.687	e Co UK	Difference	1		
			Crisis 09-12	Numerator Lag 0	-229.000	25.237	.000
				Difference	1		
*e Co UK_8**	*(0,0,0)*	*7.317*	*e Co UK*	*Constant*	*550.000*	*11.796*	*.000*
			Crisis 09-12	*Numerator Lag 0*	*-182.000*	*19.561*	*.000*
ls M GE_9	(0,0,0)	11.728	ls M GE	Constant	496.357	95.202	.000
ls M UK_10	(0,0,0)	12.546	ls M UK	Constant	1007.045	143.290	.000
ls Co GE_11	(0,0,0)	8.251	ls Co GE	Constant	190.818	16.733	.000
ls Co UK_12	(0,0,0)	6.168	ls Co UK	Constant	231.714	6.641	.000
			Crisis 09-12	Numerator Lag 0	-74.964	11.012	.000
els M GE_13	(0,0,0)	8.476	els M GE	Constant	149.652	18.727	.000
els M UK_14	(0,0,0)	7.252	els M UK	Constant	112.321	11.418	.000
			Crisis 09-12	Numerator Lag 0	-46.071	18.935	.038
els Co GE_15	(0,0,0)	7.418	els Co GE	Constant	122.182	11.036	.000
els Co UK_16	(0,0,0)	5.362	els Co UK	Constant	105.000	3.947	.000

The primary research focus of this article is to look for differences in private equity and venture capital between Germany and the UK. As plain ARIMA (0,0,0) models are best described by mean and standard error, the comparison between these models can be done by using a t-test. On the opposite, other types of time series can't statistically be compared in this manner. In terms of table 1, this applies to ARIMA (0,0,0) models with the additional parameter Crisis 09-12 causing a temporary linear shift as well as to ARIMA (0,1,0) models.

For this reason t-test statistics are only carried out for those three basic parameters of which time series are best characterized by a plain ARIMA (0,0,0) model in each country. Additional bootstrap procedures are also performed for these t-tests statistics. Basically, bootstrap is a Monte Carlo like method replacing an unknown distribution function by its empirical estimator (for more details see e.g. Efron & Tibshirani 1993 Reprint 1998; Hall 1994; Horowitz 2001; Canty et al. 2006; Fox 2015). The results are presented in table 2. They validate the tendencies from table 1 revealing statistically significant differences between Germany and the UK for total private equity investments (t M) and private equity investments into the life sciences industries (ls M) per year. This applies for the normal t-test statistics and their bootstrap procedure.

It is shown that the private equity market as a whole and its life sciences sector are both much bigger in the UK than in Germany. Going together with the model of Black and Gilson (1998), these results are in consistence with the current published empirical evidence. However, the

situation changes considerably when analyzing early stage venture capital especially for the life sciences industry. Looking at both time series of els M in table 1 and the t-test of els Co in table 2, the differences disappear with a slight albeit statistically insignificant tendency in favor of Germany. This outcome doesn't match certain trends in theory (Black & Gilson 1998; Bruton, Fried & Manigart 2005), but it supports the empirical observations that the UK market prefers other forms of private equity more than early stage financing (Murray 1999; Martin et al. 2003).

Table 2: Independent samples test and associated bootstrap of basic parameters

	Levene's Test		t-test for Equality of Means					
	Sig.	Equality of Variances	Sig. (2-tailed)	Mean Difference	Bias	Std. Error Difference	95% Confidence Interval of the Difference	
							Lower	Upper
t M	.000	Not assumed	**.000**	-15277.712		2977.374	-21863.150	-8692.273
Bootstrap[1]		Not assumed	**.004**	-15277.712	146.658	2802.898	-20615.868	-9795.702
ls M	.072	Assumed	**.008**	-510.688		172.033	-869.543	-151.833
Bootstrap[1]		Assumed	**.009**	-510.688	2.303	161.046	-806.310	-213.691
els Co	.005	Not assumed	**.167**	17.182		11.721	-8.239	42.603
Bootstrap[1]		Not assumed	**.180**	17.182	.303	11.807	-6.040	43.168

[1] All bootstrap results in all tables are based on 1000 bootstrap samples

4. Composed Parameters of Private Equity and Venture Capital

Another issue to be worth considering is the question, whether there are further differences between both countries not only for basic but also for composed parameters. Table 3 addresses the time series of deal sizes in Germany and the UK. A deal size is defined as the quotient between the sum of money and the number of companies this money was invested in. For example, Deal Size e GE represents e M GE (the sum of early stage venture capital per year invested by German venture capital firms) divided by e Co GE (the numbers of target companies per year selected by these investors). Additionally table 3 presents two deal size ratios in each case for Germany and the UK. Deal Size Ratio ls-t is defined as the quotient between Deal Size ls and Deal Size t, a similar design applies to the second one, Deal Size Ratio els-e. Both variables describe deal size relations between the life sciences sector and the entire industry, the first for total private equity, the second for early stage venture capital.

Table 3: Time series of deal size parameters

Model	Type (ARIMA)	Model Fit (Normalized BIC)	Model Parameters		Estimate	Std. Error	Sig.
Deal Size t GE_1	(0,0,0)	.900	Deal Size t GE	Constant	3.522	.424	.000
Deal Size t UK_2	(0,0,0)	4.106	Deal Size t UK	Constant	14.538	2.106	.000
Deal Size e GE_3	(0,1,0)	-4.280	Deal Size e GE	Constant	-.018	.033	.600
				Difference	1		
*Deal Size e GE_3**	*(0,0,0)*	-4.622	*Deal Size e GE*	*Constant*	*.837*	*.030*	*.000*
			Crisis 09-12	*Numerator Lag 0*	*-.172*	*0.050*	*.007*
Deal Size e UK_4	(0,0,0)	-1.328	Deal Size e UK	Constant	1.201	.139	.000
Deal Size ls GE_5	(0,0,0)	1.138	Deal Size ls GE	Constant	2.662	.478	.000
Deal Size ls UK_6	(0,0,0)	2.411	Deal Size ls UK	Constant	5.230	.903	.000
Deal Size els GE_7	(0,0,0)	-.706	Deal Size els GE	Constant	1.296	.190	.000
Deal Size els UK_8	(0,0,0)	-2.374	Deal Size els UK	Constant	1.020	.093	.000
			Crisis 09-12	Numerator Lag 0	-.338	.154	.056
Deal Size Ratio ls-t GE_9	(0,0,0)	-1.479	Deal Size Ratio ls-t GE	Constant	.797	.129	.000
Deal Size Ratio ls-t UK_10	(0,0,0)	-3.010	Deal Size Ratio ls-t UK	Constant	.385	.060	.000
Deal Size Ratio els-e GE_11	(0,0,0)	-1.059	Deal Size Ratio els-e GE	Constant	1.627	.159	.000
Deal Size Ratio els-e UK_12	(0,0,0)	-1.865	Deal Size Ratio els-e UK	Constant	.815	.106	.000

Analyzing table 3 more accurately, it can be seen that, in contrary to the basic variables in table 1, deal size variables are less affected by the financial crisis. Hence, the time series of deal sizes and deal size ratios are mostly described by plain white noise models and t-tests to compare both countries can be performed.

The outcomes are shown in the following table 4 revealing interesting and statistically significant divergences between Germany and the UK for all tested variables. Taking up the tendencies from the first two tables, the deal sizes for total private equity (Deal Size t) and for its investments into the life sciences industry (Deal Size ls) are bigger in the UK. This result endorses the already stated preference of the British market for later stage deals like management buy-outs/buy-ins (Murray 1999; Martin et al. 2003). But the situation changes as soon as early stage financing is included. Although there are no t-tests conducted for Deal Size e and Deal Size els because of the reasons described above, such tests are available for the two deal size ratios. Both of them are now evidently greater for Germany implying that the relations between the deals in the life sciences industries and their average reference values are significant bigger here than in the UK. Especially German early stage venture capital investments in the life sciences industry are much higher compared to average early stage deals causing an estimated Deal Size Ratio els-e GE of 1.627 or 162.7 %. Rather the opposite can be said about the UK. Here the relations between investments in the life sciences sector and in the entire market tend to be reversed showing a Deal Size Ratio ls-t UK of 38.5 % and a Deal Size Ratio els-e of 81.5 %. These results indicate that private equity in general and early stage venture capital in particular play a more important role for financing the German life sciences sector than their British equivalents if these segments are compared to the private equity branch as a whole.

Table 4: Independent samples test and associated bootstrap of deal size parameters

	Levene's Test		t-test for Equality of Means					
	Sig.	Equality of Variances	Sig. (2-tailed)	Mean Difference	Bias	Std. Error Difference	95% Confidence Interval of the Difference	
							Lower	Upper
Deal Size t	.001	Not assumed	**.000**	-11.016		2.148	-15.755	-6.278
Bootstrap[1]		Not assumed	**.001**	-11.016	.001	2.048	-14.506	-7.370
Deal Size ls	.037	Not assumed	**.024**	-2.568		1.021	-4.742	-.394
Bootstrap[1]		Not assumed	**.018**	-2.568	-.020	.951	-4.376	-.809
Deal Size Ratio ls-t	.016	Not assumed	**.012**	.412		.142	.107	.717
Bootstrap[1]		Not assumed	**.035**	.412	-.006	.136	.163	.657
Deal Size Ratio els-e	.808	Assumed	**.000**	.812		.191	.412	1.211
Bootstrap[1]		Assumed	**.001**	.812	-.013	.180	.520	1.128

[1] All bootstrap results in all tables are based on 1000 bootstrap samples

Further information is provided in table 5 by various ratios composed of the basic parameters. There are 16 plain ratios followed by 8 composite and more complex ratios, whereby half of the ratios refer to each country. The names of the plain ratios are directly deduced from their numerators and denominators. For example, Ratio e-t M GE is composed of e M GE divided by t M GE. Analogously Ratio els-e Co UK can be defined by els Co UK as numerator and e Co UK as denominator. The specifications for all plain ratios are given in percent of their denominators. On the other hand, a composite ratio is formed of the quotient of two plain ratios. As a consequence ES Ratio ls-t M (Co) GE (UK) consists of Ratio els-ls M (Co) GE (UK) divided by Ratio e-t M (Co) GE (UK). In the same way LS Ratio e-t M (Co) UK (GE) has the numerator Ratio els-e M (Co) UK (GE) and the denominator Ratio ls-t M (Co) UK (GE). In terms of their content, all ES ratios focus on early stage investment relations comparing the life sciences sector to the total private equity industry with respect to this issue. In contrast all LS ratios emphasize life sciences industry relations comparing early stage venture capital to entire private equity money as a whole.

Table 5: Time series of (various) ratios

Model	Type (ARIMA)	Model Fit (Normalized BIC)	Model Parameters		Estimate	Std. Error	Sig.
Ratio e-t M GE_1	(0,0,0)	3.492	Ratio e-t M GE	Constant	10.889	1.550	.000
Ratio e-t M UK_2	(0,1,0)	.890	Ratio e-t M UK	Constant	-.450	.440	.333
				Difference	1		
*Ratio e-t M UK_2**	*(0,0,0)*	*1.187*	*Ratio e-t M UK*	*Constant*	*4.630*	*.550*	*.000*
			Crisis 09-12	*Numerator Lag 0*	*-2.744*	*.912*	*.015*
Ratio e-t Co GE_3	(0,1,0)	3.013	Ratio e-t Co GE	Constant	.450	1.271	.732
				Difference	1		
*Ratio e-t Co GE_3**	*(0,0,0)*	*3.341*	*Ratio e-t Co GE*	*Constant*	*40.121*	*1.615*	*.000*
			Crisis 09-12	*Numerator Lag 0*	*7.484*	*2.678*	*.021*
Ratio e-t Co UK_4	(0,0,0)	.705	Ratio e-t Co UK	Constant	35.238	.385	.000
Ratio ls-t M GE_5	(0,0,0)	4.231	Ratio ls-t M GE	Constant	12.833	2.242	.000
Ratio ls-t M UK_6	(0,0,0)	2.463	Ratio ls-t M UK	Constant	5.753	.926	.000
Ratio ls-t Co GE_7	(0,0,0)	1.286	Ratio ls-t Co GE	Constant	15.754	.514	.000
Ratio ls-t Co UK_8	(0,0,0)	.987	Ratio ls-t Co UK	Constant	14.945	.443	.000
Ratio els-e M GE_9	(0,0,0)	5.766	Ratio els-e M GE	Constant	38.682	4.832	.000
Ratio els-e M UK_10	(0,0,0)	4.559	Ratio els-e M UK	Constant	18.450	2.642	.000
Ratio els-e Co GE_11	(0,0,0)	2.401	Ratio els-e Co GE	Constant	23.623	.898	.000
Ratio els-e Co UK_12	(0,0,0)	2.751	Ratio els-e Co UK	Constant	19.996	1.203	.000
			Crisis 09-12	Numerator Lag 0	6.490	1.995	.010
Ratio els-ls M GE_13	(0,0,0)	5.877	Ratio els-ls M GE	Constant	37.054	5.107	.000
Ratio els-ls M UK_14	(0,0,0)	5.534	Ratio els-ls M UK	Constant	14.411	4.302	.007
Ratio els-ls Co GE_15	(0,0,0)	4.486	Ratio els-ls Co GE	Constant	64.083	2.547	.000
Ratio els-ls Co UK_16	(0,0,0)	3.935	Ratio els-ls Co UK	Constant	47.456	2.174	.000
			Crisis 09-12	Numerator Lag 0	14.507	3.606	.003
ES Ratio ls-t M GE_17	(0,0,0)	1.256	ES Ratio ls-t M GE	Constant	4.497	.569	.000
			Crisis 09-12	Numerator Lag 0	-2.145	.944	.049
ES Ratio ls-t M UK_18	(0,0,0)	2.961	ES Ratio ls-t M UK	Constant	4.442	1.188	.004
ES Ratio ls-t Co GE_19	(0,0,0)	-2.946	ES Ratio ls-t Co GE	Constant	1.509	.062	.000
ES Ratio ls-t Co UK_20	(0,0,0)	-2.969	ES Ratio ls-t Co UK	Constant	1.360	.069	.000
			Crisis 09-12	Numerator Lag 0	.374	.114	.010
LS Ratio e-t M GE_21	(0,0,0)	1.241	LS Ratio e-t M GE	Constant	4.495	.565	.000
			Crisis 09-12	Numerator Lag 0	-2.173	.938	.046
LS Ratio e-t M UK_22	(0,0,0)	2.956	LS Ratio e-t M UK	Constant	4.439	1.186	.004
LS Ratio e-t Co GE_23	(0,0,0)	-2.945	LS Ratio e-t Co GE	Constant	1.509	.062	.000
LS Ratio e-t Co UK_24	(0,0,0)	-2.968	LS Ratio e-t Co UK	Constant	1.360	.069	.000
			Crisis 09-12	Numerator Lag 0	.374	.114	.010

Not unexpected and similar to deal size parameters, most ratios are expressed best by Arima (0,0,0) models. However, it has to be noted that some are significantly influenced by the additional parameter financial crisis. For example looking at Ratio e-t M UK, the yet small part of early stage venture capital in the British total private equity sector is reduced again from 4.630 % to 1.886 (4.630-2.744) % by the crisis. On the other hand, both British ratios about the number of companies for early stage money in the life sciences industry, Ratio els-e Co UK and Ratio els-ls Co UK are increased from 2009 on. Most remarkable for the German situation are the declines of both ES Ratio ls-t M GE and LS Ratio e-t M GE advising a reduction of both early stage investment relations and life sciences industry relations during the crisis.

Once more t-tests are conducted for the ratios represented by simple white noise models in each country. The results shown in table 6 demonstrate a clearly bigger role of the life sciences industry both for German private equity on the whole and particularly for early stage venture funding. The corresponding ratios Ratio ls-t M and Ratio els-e M indicate statistically significant differences between both countries. While in Germany 12.833 % of all private equity investments are made in life sciences companies, the comparative value for the UK is 5.753 %. The same outcome applies to early stage venture capital. A German 38.682 % contingent faces a British 18.450 % part. Additionally the proportion of early stage capital in the life sciences sector is also statistically greater in Germany than in the UK showing a Ratio els-ls M GE of 37.054 % compared to a Ratio els-ls M UK of 14.411 %. Altogether the results from the statistical analysis of the ratios once more confirm the previous findings, i.e. the relatively bigger importance both of life sciences and of early stage financing for private equity and venture capital in Germany compared to the UK.

Table 6: Independent samples test and associated bootstrap of (various) ratios

	Levene's Test		t-test for Equality of Means					
	Sig.	Equality of Variances	Sig. (2-tailed)	Mean Difference	Bias	Std. Error Difference	95% Confidence Interval of the Difference	
							Lower	Upper
Ratio ls-t M	.003	Not assumed	**.012**	7.080		2.426	1.852	12.308
Bootstrap[1]		Not assumed	**.039**	7.080	-.044	2.432	2.689	11.326
Ratio ls-t Co	.938	Assumed	**.248**	.808		.679	-.608	2.224
Bootstrap[1]		Assumed	**.263**	.808	.023	.674	-.472	2.145
Ratio els-e M	.447	Assumed	**.002**	20.232		5.507	8.745	31.719
Bootstrap[1]		Assumed	**.008**	20.232	.268	5.444	10.552	33.377
Ratio els-ls M	.608	Assumed	**.003**	22.643		6.677	8.714	36.571
Bootstrap[1]		Assumed	**.005**	22.643	-.012	6.512	8.771	35.432

[1] All bootstrap results in all tables are based on 1000 bootstrap samples

5. Conclusions

The preceding sections have revealed a number of differences between Germany and the United Kingdom regarding private equity and early stage venture capital investments in the years 2002 to 2012. Some of these divergences are not unexpected endorsing the existing literature, but some are quite new.

In this respect, it comes as no surprise and supports prior studies (Oehler et al. 2007; Schröder 2013) that both the British private equity market in total and its sector for the life sciences industry outweigh their German counterparts in terms of money, though this is not the case in terms of the number of invested companies. Divergent deal sizes in the private

equity branches in the two countries favoring the UK side back these results. They are the effect of the known British preference to finance bigger deals like management buy-outs/buy ins (Murray 1999; Martin et al. 2003). Quite in line with this outcome, all statistically significant discrepancies in financing volumes disappear when looking at early stage venture capital. Even without considering the above mentioned deviations in data bases at the expense of the German side, there are no significant distinctions in early stage funding between Germany and the United Kingdom both as a whole and for the life sciences. This result matches the additional evidence that differences in deal sizes favoring the UK tend to vanish or even get reversed. Although there are no t-tests available, the latter is particularly visible for early stage venture capital in the life sciences industry.

On the one hand, these findings correspond to previously published, empirical work (Jeng & Wells 2000; Martin et al. 2003; Heger, Fier & Murray 2005). They also support the significance of Black and Gilson's (1998) model for the private equity market as a whole attributing different sizes of private equity/venture capital markets to different structures of the related financial systems. On the other hand, the outcome of this study is not in line with the view expressed in a few articles (Bruton, Fried & Manigart 2005; Schröder 2013) hypothesizing about a market-centered financial system to be quasi automatically associated with a bigger market for early venture capital than a bank-centered financial system. However based on the findings of this article, the former gains no advantage over the latter as soon as early stages of entrepreneurial financing are considered. Obviously the option for future control rights through an IPO causing the superiority of market-centered financial structures in the underlying model (Black & Gilson 1998) doesn't play a significant role at this investment level. In this case, the outcome of this article confirms some prior evidence (Jeng & Wells 2000; Mayer, Schoors & Yafeh 2005), whereas it is in conflict with other previous empirical results (Schröder 2013).

Further results, in contrast, enter rather new grounds in empirical research on private equity and venture capital. This is particularly the case for the asymmetric effects of the financial crisis. Whereas this event just slightly influences the German private equity and venture capital branch by reducing early stage investment relations and life sciences industry relations, it has various more significant impacts on the British market. Especially early stage investments in the UK, both in total and for the life sciences branch, are affected negatively. Apparently the vulnerability of market-centered financial systems to certain disorders in capital markets is greater in some areas than the proneness of bank-centered systems to analogous crises. The relatively greater importance of (innovative) life sciences companies for the private equity and venture capital industry in Germany is the second new but neither unexpected nor unpredictable outcome of this study. First, its evidence is revealed by significant differences in the money ratios between life sciences and total private equity as well as between life sciences and total early stage capital. Second, this finding goes hand in hand with significant inequalities in the two deal size ratios pointing out bigger relations between the deals in the life sciences industries and their average reference values in Germany compared to the UK.

As in any empirical work, there are some limitations in this study. First, private equity and venture capital investments are not typically part of a public financial market. Therefore all data in this field are to a certain extent restricted and often not standardized. Because of this, some data used in this work are not completely equivalent. As already discussed, especially the comparison between British and German early stage financing is hereby affected. The second reservation refers to the statistical problem how to compare financial developments

over time from various countries. To the authors' knowledge, this is only possible for mean models in a statistically applicable way. For other time series, e.g. upward trends with different starting points and different gradients, a sense-making statistical approach doesn't exist.

Bringing it all together, the divergent sensitivities to capital market disturbances between both countries can particularly be seen as an interesting result. It is well suited for subsequent theoretical and empirical research not only to analyze cross-national differences in venture capital but also to get a comprehensive view on the structural advantages or disadvantages of market-centered and bank-centered financial systems. Together with the absence of any significant disparity in early stage financing between Germany and the UK, this outcome should give occasion to reinvestigate the view that the characteristics of bank-centered financial systems have generally a negative impact on all venture capital investments.

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