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Who do you trust while bubbles grow and blow?

A comparative analysis of the explanatory power of accounting and patent information for the market values of German firms

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Abstract:

We present a theoretical and empirical analysis of the fitness of national German (German Commercial Code – *Handelsgesetzbuch (HGB)*) and international (IAS and US-GAAP) accounting information, as well as European patent data to explain the market values of German manufacturing firms. For the chosen volatile period from 1997 to 2002, cautious national accounting information does not correlate with the firms' residual market values (RMV). International accounting information makes no meaningful contribution to explaining firms' RMV and seems to measure over-investment only. Finally, patents counted at the individual country level correlate with the firms' RMV.

Keywords: Accounting standards, investor information, market value, patents

JEL-Classification: D82, M40, M41, K11

Non Technical Summary

The present paper studies the suitability of data based on national accounting standards (Commercial Code), international standards (IAS and US-GAAP) and publicly available patent information for explaining the market value of listed corporations in Germany. Theory holds that balance sheet information on intangible assets based on international accounting standards should have greater explanatory power than the balance sheet information contained in national annual accounts. This is because international accounting standards seek to value assets as close to real time as possible while, in some cases, allowing the capitalisation of intangible assets. In particular, international accounting rules ought to prove their worth specifically in periods of volatility. Since balance sheet information naturally tends to be backward-looking, this paper also studies the question of whether patent information, which tends to be forward-looking, is suitable for explaining market values.

The empirical analysis produces very different results for the 1997-2002 observation period. In the theoretical model used here, intangible assets listed on the balance sheet in accordance with national accounting rules (Commercial Code) made no contribution to explaining the market value of listed enterprises. This does not come as a surprise, considering that national accounting rules forbid the capitalisation of self-constructed intangible assets. By contrast, intangible assets valued in line with international accounting rules and market values were found to be negatively correlated. The fact that share prices tended to be overvalued during this observation period may be one reason for this unexpected result. When market players perceive these overvalued shares (speculative bubbles), this leads to the empirically detected negative correlation. Finally, the empirical studies show that, for most companies, patent information makes a positive contribution to explaining market values. Information that serves as a measure of future profitability is accordingly a meaningful complement to classical balance sheet information.

Nicht technische Zusammenfassung

In der vorliegenden Forschungsarbeit wird untersucht, wie Angaben auf der Basis nationaler Rechnungslegung (HGB), internationaler Rechnungslegung (IAS und US-GAAP) sowie von öffentlich verfügbaren Patentinformationen geeignet sind, Marktwerte börsennotierter Kapitalgesellschaften in Deutschland zu erklären. Nach theoretischen Überlegungen sollten Bilanzinformation zu immateriellen Vermögenswerten auf Basis internationaler Rechnungslegung einen größeren Erklärungsbeitrag liefern als Bilanzinformationen nationaler Jahreabschlüsse. Grund hierfür ist, dass die internationale Rechnungslegung einerseits das Ziel hat, Vermögenswerte möglichst realitätsnah zu bewerten. Andererseits lässt sie teilweise die Aktivierung von intangiblen Vermögensgegenständen zu. Insbesondere sollte sich eine internationale Rechungslegung gerade auch in Zeiten volatiler Kurse bewähren. Da Bilanzinformationen naturgemäß eher vergangenheitsorientiert sind, wird in der vorliegenden Arbeit auch der Frage nachgegangen ob Patentinformation, die eher in die Zukunft weisen, für die Erklärung von Markwerten geeignet sind.

Für den Untersuchungszeitraum von 1997 bis 2002 kommt die empirische Analyse zu sehr unterschiedlichen Ergebnissen. Im Rahmen des verwendeten theoretischen Modells haben immaterielle Vermögenswerte, die nach nationaler Rechnungslegung (HGB) bilanziert wurden, keinen Erklärungsbeitrag für Marktwerte börsennotierter Unternehmen. Dieses Ergebnis ist vor dem Hintergrund, dass nach nationaler Rechnungslegung ein Aktivierungsverbot für selbsterstellte immaterielle Vermögens-werte besteht, nicht überraschend. Zwischen immateriellen Vermögensbestandteilen auf Basis internationaler Rechungslegung und Marktwerten wurde dagegen ein negativer Zusammenhang festgestellt. Ein Grund für dieses unerwartete Resultat kann in dem tendenziell durch überbewertete Börsenkurse gekennzeichneten Untersuchungszeitraum liegen. Sofern Marktteilnehmer diese Überwertungen (spekulative Blasen) wahrnehmen führt dies zu dem empirisch festgestellten negativen Zusammenhang. Schließlich zeigen die empirischen Untersuchungen für die Mehrzahl der Unternehmen einen positiven Erklärungsbeitrag von Patentinformationen zu den Marktwerten. Informationen, die ein Maß für die künftige Ertragslage sind, stellen demnach eine sinnvolle Ergänzung zu den klassischen Bilanzinformationen dar.

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1 Introduction♠

The national accounting standards and disclosure requirements are an integral part of the institutional infrastructure and thus of a country's financial system. According to the approaches adopted in neo-classical literature, the proper operation of efficient capital markets is closely related to the infrastructure of the financial systems. It is thus undisputed that the accounting standards are assigned a key role as an instrument for generating information. Different opinions are held as to which type of information should enter accounting data, and which type should be publicly disclosed outside the firms' books. While Ball (2001) argues in favour of excluding any expectational data from the financial reporting in order to avoid principal agent problems between investors and managers, others (see Lev and Sougiannis, 1996; Lev and Zarowin, 1999) postulate an extension of the boundaries of accounting when 'classical' reporting standards fail to inform investors realistically. While it seems fair to say that most accounting systems as of today are still rather cautious in that measures for expected profits cannot usually be capitalised, differences still exist across (inter)national accounting systems and these are commonly held to play out in the standards' suitability for informing investors. The case of Germany provides an excellent example.

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Generally speaking, two different types of accounting standards are used in Germany. On the one hand we have the Anglo-Saxon system (IAS, US-GAAP, and IFRS), which tends to be more capital market-based, and on the other the German system (HGB), which tends to be more bank-based (relationship-based). The major institutional changes which have occurred in the German financial system since the mid-1990s represent a substantial shift towards the internationalisation of accounting standards. This major change is largely attributable to the globalisation of financial markets and to the associated requirements concerning the structure of the institutional environment. Globalisation of international financial markets in Germany led to a significant increase in the market capitalisation of firms already listed, the establishment of new market segments (Neuer Markt and SMAX), and the listing of numerous small and in particular, innovative firms in these market segments. These market segments represented a financing source that was largely the preserve of the major traditional firms in Germany until the early 1990s. This financing solution enabled innovative firms to rely far less on traditional debt financing. In this context, empirical studies for Germany indicate financing constraints on innovative firms. Lack of transparency is frequently cited as one of the reasons for possible financing constraints, inter alia due to the fact that small firms are not obliged to comply with disclosure requirements. This was one of the reasons why disclosure in accordance with internationally recognised accounting standards became one of the requirements in establishing the Neuer Markt.[3]

One significant aspect attributed to international accounting standards by their proponents is that asset values are marked to market as closely as possible. In conjunction with an improvement in the information available to capital market participants about firms, this should lead to greater transparency within the financial system. Where international accounting standards fulfil the requirements of reducing the information asymmetry between providers and recipients of capital, the valuation of firms using these principles should correlate as closely as possible to the market value. It is interesting to note that, to date, changed accounting standards in Germany and their fitness for capturing market values have been discussed mainly from a theoretical perspective,[4] giving rise to two interesting questions from an empirical viewpoint:

[3] Another obvious reason were standardization advantages.
[4] The paper by Spanheimer/Koch 2000 is an exception. Besides, it is restricted to univariate analysis.

1. Has the introduction of international accounting standards for firms listed on the Neuer Markt, SMAX, and DAX resulted in an improvement in information such that firms can be marked more accurately to market?

The question appears particularly interesting in the light of Lev and Sougiannis (1996), Aboody and Lev (1998), and Lev and Zarowin (1999) who can demonstrate for the U.S. that the power of international accounting data to inform investors in high-technology firms has decreased over the years.

Also, along the same general line of thought, we wonder whether the objective of stable capital markets and its imperative for accountants to generate information on firms which is as precise as possible[5] justifies the incorporation of additional publicly available information sources in the annual financial statements. Thus, our second guiding question is

2. Is there additional firm-relevant and publicly-available information to meet the requirements of providing investor-relevant information and minimising principal agent risks?

This paper attempts to contribute to answering both questions. Like Lev and Sougiannis (1996), Aboody and Lev (1998), and Lev and Zarowin (1999) it focuses on corporate assets particularly relevant yet difficult to assess for outside capital providers, namely intangible assets. As a means to overcome the information asymmetries between firms and outside investors regarding these immaterial firm values, the suitability of publicly available patent information as an additional information source is tested (see Hirschey and Richardson, 2004, for a very recent paper which takes a similar approach on US data). It is noteworthy that patent data have the major advantage of being by definition expected output measures of R&D but, owing to the patentability requirements, are still not fully endogenous from a management perspective and hence create fewer agency problems than other data.

To the best of our knowledge, this analysis is the first major empirical study that analyses the significance of different accounting standards and patent information for explaining market value. We deliberately restrict ourselves to the period from 1997 to

[5] This optimization problem involves trading-off the abstract suitability of information sources for investors against the associated principal agent risk between shareholders and managers.

2002, which tends to be characterised by volatile market prices. International accounting standards should provide a more market-compliant valuation than national German standards, in particular during periods of general uncertainty and hence unstable capital markets through growing and bursting bubbles. Patent data should contain additional explanatory power (providing an expected output measure) which complements financial reporting data (capitalising costs as an input measure).

Our empirical study is based on a q-model which examines the market value of listed corporations in Germany. The analysis uses annual financial statements prepared in accordance with national (HGB) and international accounting standards (IAS and US-GAAP), and information from the European Patent Office (EPO). It encompasses 540 firms from the DAX, Neuer Markt, and SMAX market segments for the sample period 1997 to 2002.

The remainder of the article is structured as follows. Section 2 describes the underlying theory and presents the hypotheses for the empirical study. Section 3 describes the data sources and the generation of the key variables used in the study. The data are described in section 4, while section 5 presents the inference statistical results. Section 6 summarises the results and outlines other planned work on the subject.

2 Theoretical background

2.1 Accounting regulations in Germany– types and objectives, principles and practice

The literature typically differentiates between two accounting systems. On the one hand we have the arm's-length or outsider system and, on the other, the relationship-based or insider system (Franks/Mayer, 1994; Rajan/Zingales, 1998; Allen/Gale, 2000 and Nowak, 2001). These two systems differ with respect to the way capital flows through which transmission channels to the investment alternatives, the provision of guarantees to investors and the degree of information asymmetry between the counterparties (providers of equity or debt capital). Outsider systems are distinguished above all by the close (arm's-length) relationship between investors and the firm, and by an accounting system geared towards informing investors as comprehensively as possible. In contrast, relationship systems are defined by a close relationship between firms and providers of

debt capital (banks or other financial intermediaries). These systems are also distinguished by an accounting regime that creates incentives to facilitate external funding through borrowing. Within such a system, other "private" sources for the procurement of information are therefore relevant to potential investors. Accordingly, the US and UK financial and accounting system (US-GAAP and IAS) can be classified as an outsider system and the German HGB as an insider system.

In addition to the codified legal provisions for the annual financial statements, HGB comprises further rules – the German Generally Accepted Accounting Principles (*Grundsätze ordnungsgemäßer Buchführung – GoB*). Similar to IAS, GoB does not represent any legal code, but originates from cooperation between different standardising institutions (auditors, academics, and courts). GoBs are regarded as generally recognised regulations concerning the management of commercial balance sheets and preparation of annual financial statements. This is understood in the relevant literature on business economics as the principles of accuracy and impartiality, clarity and completeness, the principles of delimitation and the principles of consistency and prudence.[6] These rules are salient features of HGB. For IAS, specific rules were developed for the preparation of annual financial statements – the qualitative characteristics. The four characteristics are the principles *understandability*, *relevance*, *reliability*, and *comparability*.[7] US GAAP likewise comprise a variety of general principles, standards related to individual cases and usual procedures. The fundamental objective of US-GAAP is the so-called *decision usefulness*, from which the qualitative requirements of the annual financial statements are derived. The four main characteristics are *relevance*, *reliability*, *comparability* and *consistency*. A comparison of the objectives and rules of HGB and international accounting standards shows that the principle of prudence plays a minor role within the scope of international accounting, and the connotations for assets differ. The accrual basis of accounting dominates the principle of prudence within the scope of HGB and is reflected in the principle of lower of cost or market. International standards differ in that not only profits already realised are recognised, but also profits that are likely to be realised.

[6] Compare eg Coenenberg 2000.
[7] Compare eg Coenenberg 2000.

Valuation in accordance with international accounting standards therefore tends to be more realistic as opposed to HGB which can be described as retrospective.

Accounting in Germany has changed fundamentally in recent years due to the introduction of international accounting standards in the German accounting system. The switch to international accounting standards is illustrated especially by the provisions on the publication of accounting figures drawn up by Deutsche Börse for Neuer Markt and SMAX. Deutsche Börse's rules and regulations specify that, with the start of this market segment, accounting must be in accordance with internationally accepted accounting standards (IAS or US-GAAP).[8] Since then, firms listed in the DAX are also obliged to report in accordance with international accounting standards (IAS or US-GAAP).

2.2 The suitability of (inter)national accounting standards for intangible fixed assets – theoretical deliberations and empirical findings

One of the key differences between German accounting in accordance with HGB and international accounting standards (IAS, US-GAAP) is the balance sheet treatment of intangible fixed assets.[9] In the HGB, the valuation of intangible fixed assets is regulated in section 253 (2.), IAS 38 applies under IAS, while US GAAP is heavily characterised by discretionary regulations and accounting practice. In general, one must differentiate between own work and assets acquired against a consideration. There are no major differences between national and international accounting standards with regard to assets acquired against a consideration. With regard to self-produced intangible assets, there are differences between the systems under consideration. Under HGB (section 248 (2) HGB) and US GAAP, the capitalisation of intangible fixed assets is fundamentally

[8] The objective of the International Accounting Standards Committee Foundation (IASC Foundation) is the development and interpretation of international accounting standards. The German Accounting Standards Committee (Deutsche Rechnungslegungs Standards Committee – DSRC) is also committed to advising the German Federal Government.

[9] A detailed comparison of both accounting standards can be found inter alia in Leuz/Deller/Stubenrath (1998) and Leuz/Wüstemann (2003).

impermissible. While IAS prohibits the capitalisation of research expenditure (IAS 38.42 ff.), a capitalisation of development expenditure (IAS 38.45) is possible under certain valuation criteria (IAS 38.46).[10]

Accounting in accordance with international standards could represent an advantage for valuing technology firms listed in Neuer Markt and TecDax, since it leads to significant changes in the balance sheet structure compared to national German standards.[11] In particular, expenses for internally produced developments may be capitalised. Admittedly, by restricting activation to expenses (and not expected profits), even international accounting standards treat intangible assets somewhat more cautiously than other assets. However, investors are supposed to view this additional information as positive, since for example, costs for internally produced patents should reflect a firm's future profit potential and can therefore be relevant to its valuation.[12] Unlike accounting in accordance with HGB, the information should facilitate a much more "realistic" valuation of intangible fixed assets. While the introduction of international accounting standards in Germany is largely welcomed in the literature, recent experiences with Neuer Markt and scandals in the US (Enron) also demonstrate their limitations.

To the best of the authors' knowledge, no econometric analyses have yet been carried out on the differences between accounting standards. Nonetheless, there is a whole raft of empirical analyses that examine the correlation between market values on the one hand and balance sheet and patent variables on the other. These studies do not follow the same objectives as this paper. However, they are methodologically comparable to the q-approach taken in this paper.[13] A common finding of the papers by Cockburn and Griliches (1988) and Megna and Clock (1993), Conolly et al (1986), Conolly and Hirschey (1988), Lev and Sougiannis (1996), Bloom and van Reenen

[10] A capitalisation of research expenditures is also possible under US GAAP in some cases. In the present sample (see below) positive values are also found for enterprises following US-GAAP accounting practice. Not least for this reason, both sub samples (IAS and US GAAP) were combined for the empirical analysis.

[11] From an accounting perspective, capitalisation of intangible fixed assets leads to a balance sheet extension that must also show up on the liabilities side. It is possible here to increase capital by retaining profit, increasing provisions or expanding additional borrowing.

[12] See, however, Lev and Zarowin (1999) for the potential information distractions if only expenses and not profits may be capitalized. This point will be discussed in more detail below.

[13] Compare 2.5 for a detailed explanation of the *q*-approach. Compare Table 1 in Hall et al (2000) for a comprehensive synopsis of the studies.

(2000), Hall et al (2000), Bosworth and Rogers (2001), and Hirschey and Richardson (2004) is that R&D expenditure and patent variables[14] calculated in different ways furnish some explanatory power for measuring the market value of firms. There are, however, three key differences with respect to the data sources and the formation of variables, which should be touched on briefly.

Firstly, the annual accounts of listed firms generally provide the opportunity to use bookvalues of tangible assets or the tangible assets from the asset history sheet (*Anlagengitter*). The difference between these two variables lies in the tax depreciation of tangible fixed assets. The asset history sheet contains all the firm's relevant assets recorded at historical acquisition costs by book entry. Using book values – such as in Conolly et al (1986), Conolly and Hirschey (1988), Hall et al (2000) and Bloom and van Reenen (2000) – thus tends to undervalue the capital stock, while the use of historical acquisition costs – Megna and Clock (1993) – should tend to be more closely correlated to the true value.[15] This closer correlation is likely to exist mainly if the tax write-downs on the book values are largely independent of the economic write-downs. It is precisely in the case of intangible fixed assets, however, that the definition of economic write-downs is likely to be fraught with problems since the decrease in the value of these assets is difficult to determine.

Secondly, the variables for tangible and intangible fixed assets vary in relation to the analysis level at which they are aggregated. Intangible fixed assets in accordance with IAS and US-GAAP are classified in the four sub-items (1) concessions, patents and licences, (2) capitalised development costs, (3) goodwill and (4) other intangible fixed assets. Goodwill in particular poses a problem when using total intangible fixed assets. By definition, in the event of a take-over this is reflected as the difference between the assets eligible for capitalisation less debt and the acquisition price paid.[16] Goodwill is therefore not offset by any objective variable, and the use of total intangible fixed assets tends to result in overvaluation of the carrying amounts – as Conolly et al

[14] Compare 2.3 for the discussion about the results regarding the patent variables.

[15] To calculate q, tangible fixed assets must be calculated at their replacement cost. To this end an adjustment factor is typically used for the first observation of the time series. This adjustment factor is determined using aggregate figures that cannot adequately take into account the heterogeneity of the micro data. In the case of large data records, therefore, the replacement cost cannot be precisely determined.

[16] Compare Coenenberg (2000).

(1986), Conolly and Hirschey (1988), Hall et al (2000), Bloom and van Reenen (2000). Bosworth and Rogers (2001) take this aspect into consideration in their paper.

Thirdly, there is a difference in the manner in which the variable for R&D expenditure is used in the profit and loss account (P&L). By definition, only expenses attributable to the reporting period should be recognised in the P&L.[17] Hence the data record must comprise the entire accounting history in order to calculate the capital stock precisely. This could prove difficult, since firms under a certain size are typically not obliged to disclosure, which would tend to lead to underestimation of the capital stock – as in Cockburn and Griliches (1988) and Megna and Clock (1993). However, this variable has an advantage as well. In contrast to the development costs capitalised in the balance sheet, research expenditure can also be offset. Accordingly, if firms report significant investment in research and this cannot be capitalised, the sole use of items from the balance sheet results in a corresponding underestimation of the capital stock carrying amounts. Griliches (1988), Cockburn and Griliches (1988), Conolly et al (1986), Conolly and Hirschey (1988), Megna and Clock (1993), Hall et al (2000), Bloom and van Reenen (2000) use total R&D expenditure from the P&L.

2.3 Patent information – availability and suitability for accounting

Patent information must be published in all relevant jurisdictions,[18] which suggests the possible use of patent information as a further source of balance sheet information. But first we must consider to what extent patent information corresponds from a theoretical perspective to the balance sheet principles of the different accounting standards and what empirical findings underpin these considerations.

From a national German perspective, patent information would be appropriate for accounting usage if it could be capitalised in accordance with the GoB principles (c.f.

[17] In accordance with IAS and US-GAAP only. Compare above.

[18] The scope of this information varies from jurisdiction to jurisdiction. The world's most important patent systems (Europe, US, Japan) agree that information on the applicant, inventor, invention, the sought-after scope of protection and the examination procedure, including key findings, must be published. NB: the information (official costs) provides an indirect source only of financial information. The expected value of the invention is not explicitly referred to. In Europe, information is always published after a disclosure period of 18 months after the first application date. This provision applies meanwhile in the US as well.

2.1) of (a) *accuracy,* (b) *impartiality,* (c) *clarity* and (d) *completeness,* and could be *valued consistently* and *prudently*.

The question of whether information is the "correct" information is difficult to answer, even for standard cases; it is therefore obviously all the more difficult to make a general assessment of the accuracy of patent information.[19] Without an in-depth knowledge of the relevant case law, it would nonetheless seem that the information conveyed by patent information is not at odds with the principle of *accuracy*.[20] Furthermore, the use of patent information appears neither qualitatively wrong nor partial. The principle of *clarity* is likewise more a request addressed to the accountants than a general restriction on the use of patent information. The same applies to the principle of *completeness*. As the authors see it, the answer to the question of whether patent information can be valued *consistently* and *prudently* is also affirmative. Pursuant to the strict principle of lower of cost or market and the *imparity* principle, at least the patent application costs can be clearly quantified and allocated to the relevant period with profit-reducing effect.[21] From a national German accounting perspective, the authors do not actually see any obstacle, content-wise or theoretical, to entering patent information in a separate expenditure category in the P&L.[22]

A mooter point is to what extent the inclusion of patent information can help realise the objective of international accounting standards of achieving "realistic" valuation. While the requirements of *understandability* (IAS), *comparability* (IAS and US-GAAP) and *consistency* (US-GAAP) appear uncritical, the summary assessment of the *decision usefulness* particularly raises the question as to what extent patent

[19] The principle of accuracy prohibits all manipulation that could lead to factual adulteration of the accounts and therefore complements the principle of completeness. The principle of accuracy and veracity implies that business transactions that have not really taken place or which need not be accounted for as defined by the principles of completeness may not be entered. All accountable business transactions must be identified correctly in terms of quality and quantity. Qualitative accuracy means entering the actual content of the business transactions. Quantitative accuracy requires the correct amount to be entered.

[20] The official registration obligation for patents ensures that patent information cannot be manipulated unnoticed. This applies at least to patent information after the 19th month from the first application date on which it is disclosed

[21] See also the necessity for quantitatively "correct" capitalisation (fn 13)

[22] This generally comprises costs for legal advice, costs for applying to the patent office and if necessary, examination and translation fees.

information is sufficiently *relevant* and *reliable* to be able to optimally capture future expected returns.[23]

From a theoretical perspective, self-application patents represent protection mechanisms for a firm's research and development (R&D), whereby it is obvious that these investments in R&D are linked to an expected return (see also Lev and Sougiannis, 1996, for the amortisation of R&D expenses). Hence it makes sense to assume that the number of patents owned by a firm should correlate with the true value of its intangible fixed assets. From a theoretical perspective, the patent information should be a valid (*relevant*) intangibles' stock correlate. Admittedly, this consideration does not immediately solve the quantification problem for patent data. Speaking with the fervent asserters of prudent reporting (for example,. Ball, 2001), an objective valuation of the patent data would be required to include the information in the financial reporting. While the current literature does not provide solutions to casuistic problems, the series of empirical findings from repeated studies nevertheless suggests that capitalisation with an average expected profit could be a reasonable approximation in aggregate. In order to capitalise intangibles in accordance with international accounting standards, the number of patents owned by a firm could therefore conceivably be multiplied by an average expected return rather than by the average application costs (the latter being in line with the principle of lower of cost or market as defined by HGB).[24] The earlier empirical studies already discussed in 2.1 convey an impression of

[23] Note that by imposing this criterion we even demand more from the patent information than from 'traditional' information to capture intangibles.

[24] From a theoretical perspective, multiplying a simple patent count variable with an average value of course gives rise to reservations in various respects. In the excurse given below, we describe the major two reservations and provide suggestions as to how to tackle them: On the one hand, empirical studies (see Levin et al, 1987, Harabi, 1995; Cohen et al, 2000) show that the significance of using patents for the appropriation of returns from innovations comes into effect especially in technology-intensive industries and to a varying degree in discreet and complex technologies. (Merges and Nelson (1990) distinguish between discreet (less) and complex (more) technologies according to the number of patentable elements per invention). Although the most recent empirical analyses confirm that the number of patents per invention can in fact fluctuate sharply (please refer to Arora et al, 2002; Reitzig, 2004), the patenting requirements specify that the number of trademarks that can be registered per invention is not however a totally endogenous variable. In general, patent information evidently remains suitable as an indicator variable for expected returns. Nevertheless, the firm's industry must be taken into account. Secondly the assumption that the distribution of executed innovation projects (and corresponding patent values) is negatively skewed is meanwhile a fixed component of theoretical innovation economy (please refer to Harhoff et al, 1999, and Reitzig, 2003 for the latest empirical evidence). Consequently, a quality weighting of the pure number of patent applications appears appropriate in order to increase their suitability in illustrating realistic potential returns technology firms.

reliability in the statistical sense.

These analyses are listed in detail in Hall et al (2000) and Bosworth and Rogers (2001). We will only touch on them below with respect to their most important similarities and differences for this paper. The central and most important outcome of all studies is that patent variables in all analyses show a significant positive correlation with the firm's market value.[25] Despite (or because of) the differences between the studies, patent information appears to be a reliable indicator of firms' market value. A consensus prevails among the studies' authors that patents represent a measure of expected return from R&D activities. [26] However, due to the specific characteristics of the individual studies, it is difficult to compare the coefficients for quantifying the effects that were found in earlier studies.[27] As a rule, the results from earlier studies differ along four important dimensions – (1) the nationality of the firms and patents in questions, (2) the data quality, (3) representation of the patent variable as a flow or stock variable, and (4) the quality weighting of the patent variable.

While the papers by Cockburn and Griliches (1988), Megna and Clock (1993), Conolly et al (1986), Conolly and Hirschey (1988), and Hall et al (2000) examine US firms and patents, Bloom and van Reenen (2002) resort to UK patent information. Bosworth and Rogers' study (2001) examines the correlation between the market values and patents of Australian firms, whereby it can be assumed that Australian patent information was used.[28] Hence, differences between the identified coefficients in the aforementioned studies can in theory also be due to the feature of the US patent system that was in place until recently, where patent information was not published until after the patent was granted, so that the information effect of the patents for investors could be subject to a delay. Furthermore, the sizes of the samples vary (both in cross section and in longitudinal section). While Hall et al (2000) create patent variables for patents granted to approx. 1,700 firms per annum in a panel covering the period from 1965 to 1995, Bosworth and Rogers' study (2001) extends over a cross-section of patents registered in 1996. Consequently, the patent variable in the Bosworth and Rogers study

[25] NB: this does not apply to all tested specifications in the publications mentioned.

[26] See explicitly Megna and Klock (1993), p 268. Cockburn and Griliches (1988), however, also express the presumption that patent variables are "poorer" proxy variables for a firm's R&D output than balance sheet information is for the R&D input.

[27] See Bosworth and Rogers (2001) for a corresponding attempt (Table A1).

(2001) is included as a flow variable, while the analyses of Cockburn and Griliches (1998), Hall et al (2000), and Bloom and van Reenen (2000) use (cumulative) stock variables.[29] This difference seems crucial for the "explanatory power" of patent information with regard to market value, since increasingly important cumulative research and development (Scotchmer, 1991; Green and Scotchmer, 1995; Scotchmer, 1996) should be better captured by a stock rather than a flow variable. Finally, the recent papers by Hall et al (2000) and Bloom and van Reenen (2000) take into account that the distribution of patent values is left skewed and can be plausibly weighted using the measure of (extrapolated) forward citations (Trajtenberg, 1990).

In summary, it is found that patent information, from the perspective of international accounting standards, is a valid and reliable indicator of expected returns from R&D. Quantification of simple patent counts is nevertheless significant and the extent of potential individual errors for individual firms is not obvious from the statistical studies.

2.4 Deriving the hypotheses

The above theoretical considerations suggest several hypotheses which are tested in the course of subsequent analyses. Four out five hypotheses relate to the residual (market-based) firm value which is understood as the market value of a listed firm plus its debt minus the firm's material assets.

H1: During periods of volatile market prices, there is no significant correlation between intangible fixed assets reported in accordance with HGB and the true residual value of a firm.

H2: During periods of volatile market prices, there is a significant positive correlation between intangible fixed assets reported in accordance with international accounting standards and the true residual value of a firm.

H3: During periods of volatile market prices, there is a significant positive correlation between the cumulative number of patents and the residual true value of a firm..

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[28] This information is not obvious from the Bosworth and Rogers study (2001).

[29] The authors were unable to distinguish such a clear-cut distinction in the studies of Megna and Clock (1993), Conolly et al (1986) and Conolly and Hirschey (1988).

H4: During periods of volatile market prices, there is a significant difference in the explanatory power of intangible fixed assets reported in accordance with (1) HGB and (2) international accounting standards for the residual true value of a firm.

H5: The correlations described in H2 and H3 are not identical; intangible fixed assets reported in accordance with international accounting standards and the cumulative number of patents add up in their power of explaining a firm's residual true value.

2.5 Model and estimation

In order to test Hypotheses 1 to 5, we use the established approach of Brainard and Tobin (1968), which is typically described in the literature as Tobin's q. Similar to Griliches (1981) and many other subsequent papers (Cockburn and Griliches, 1988; Megna and Klock, 1993; Bloom and van Reenen, 2000; Hall et al, 2000), we proceed from the assumption of an iteratively separable linear market value function at firm level. This model assumes equal distribution of the marginal shadow value of the assets among the sampled firms. Equation 1 formalises the correlation for constant economies of scale

$$V_{i,t} = q_t \cdot \left(A_{it} + \gamma_i \cdot K_{it}\right) \quad (1),$$

where A_{it} denotes the nominal tangible fixed assets and K_{it} the nominal intangible fixed assets. Applying logarithms and transforming Equation 1 gives us Equation 2

$$log\left(\frac{V_{i,t}}{A_{i.t}}\right) = log\, Q_{i,t} = log\, q_t + log\left(1 + \gamma_i \frac{K_{it}}{A_{it}}\right) \quad (2),$$

which, assisted by the simplification $log(1+x) \approx x$ for small x, is already used as a basis for estimating Tobin's q in a number of empirical analyses. The latter simplification, however, does not appear justified for the data examined in this paper.

Equation (2) is therefore to be estimated either non-linearly or has to be linearised before an estimation. Possible estimation techniques, in the order of their theoretical plausibility, are panel instrument variable estimation procedures (GMM), panel

estimation procedures without instrumentation (random effects and fixed effects) or OLS, which construes the data as pooled cross-sectional data. In the following paper, we present regression results based on two estimation procedures. Since the preferred variant of a GMM estimation,[30] did not provide interpretable results owing to a lack of suitable instruments, we present only the results of a non-linear pooled cross-sectional estimation based on equation (2) as well as the results of a fixed effects estimation for which we linearise equation (2).[31] According to Greene (2003, pp 165-166), we linearise the model and transfer Equation 2 into the general Equation 3:

$$y_{it} = \alpha_i + f\left(x_{it} \cdot \beta\right) + \varepsilon_{it} = \alpha_i + f\left(x_{it} \cdot \beta^0\right) + \frac{\partial f\left(x_{it} \cdot \beta^0\right)}{\partial \beta^0}\left(\beta - \beta^0\right) + \varepsilon_{it} \quad (3),$$

where

$$y_{it} = log\left(\frac{V_{it}}{A_{it}}\right), f\left(x_{it} \cdot \beta\right) = log\left(1 + \gamma_{it}\frac{K_{it}}{A_{it}}\right)$$

and

$$\frac{\partial f\left(x_{it} \cdot \beta^0\right)}{\partial \beta^0} = \frac{\frac{K_{it}}{A_{it}}}{1 + \gamma^0_{it} \cdot \frac{K_{it}}{A_{it}}}$$

The objective here is to estimate the equation using a fixed effects approach where the error term ε_{it} is decomposed into a fixed effect (η_i), a time effect (τ_t) and a stochastic error term (υ_{it}). Transforming Equation 3 gives us Equation 4

[30] From a theoretical standpoint, GMM estimation procedures are generally to be preferred in that they take account of firm-specific and also capture potential endogeneity problems in Equation (2).

[31] All the tests (see below) indicate the presence of a firm-specific effect. In interpreting them, the fixed effects estimation is therefore to be preferred to the random effects model and the pooled cross-sectional estimation. The endogeneity problem continues to exist in both estimations. The fixed effects approach is, however, more realistic in modelling how potential investors, when assessing the value of the enterprise, do not consider balance sheet information independently of firm-specific effects.

$$y_{it}^{*} = y_{it} - f\left(x_{it} \cdot \beta^{0}\right) = \alpha_i + \frac{\partial f\left(x_{it} \cdot \beta^{0}\right)}{\partial \beta^{0}}\left(\beta - \beta^{0}\right) + \varepsilon_{it} \qquad (4),$$

in which the coefficient $\left(\beta - \beta^{0}\right)$ is now estimated. Equation 4 thus allows the indirect calculation of the required for pooled cross-section and panel data[32] and is used for hypothesis tests 1 to 3. The intangible capital stocks K_{it} are operationalised (proxied) in separate estimates by (1) intangible fixed assets according to national accounting standards and (2) international accounting standards and (3) cumulative patent numbers.

To test Hypothesis 4, Equation (4) is extended to include an additional variable which differentiates between observations based on financial statements prepared in accordance with national and international accounting standards.[33]

$$y_{it}^{*} = y_{it} - f\left(x_{it} \cdot \beta^{0}\right) = \alpha_i + \frac{\partial f\left(x_{it} \cdot \beta^{0}\right)}{\partial \beta^{0}}\left(\beta - \beta^{0}\right) + \delta \cdot FinStatType + \varepsilon_{it} \qquad (5)$$

Finally, Hypothesis 5 is tested by extending Equation 5 so that all proxy variables for intangible fixed assets can be estimated in one common model (n=1: HGB; n=2: IAS/US-GAAP; n=3: patent information). Equation 6 shows this correlation:

$$y_{it}^{*} = y_{it} - \sum_{n=1}^{3} f\left(x_{n,it} \cdot \beta_n^{0}\right) = \alpha_i + \sum_{n=1}^{3} \frac{\partial f\left(x_{n,it} \cdot \beta_n^{0}\right)}{\partial \beta_n^{0}}\left(\beta_n - \beta_n^{0}\right) + \delta \cdot FinStatType + \varepsilon_{it} \qquad (6)$$

In contrast to Equations 4 and 5, the coefficients in Equation 6 can no longer be meaningfully interpreted structurally. [34]

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[32] For this purpose, Equation 4b is iteratively estimated until the coefficient $\left(\beta - \beta^{0}\right)$ converges towards zero. The value of the true γ_{it} from Equation 3 can then be calculated.

[33] For most firms consolidated financial statements are available in accordance with either national or international accounting standards. Furthermore, the sub-samples in Hypothesis tests 1 and 2 vary and the expected difference in the explanatory power of the different accounting standards can only be determined for the entire sample. Two dummy variables are used here to differentiate between the financial statements prepared in accordance with the different accounting standards.

Overall, the choice of a non-linear estimation approach allows us methodologically to draw a direct comparison with the recent papers by Hall et al (2000), whereby we are – as mentioned – not restricted to the pooled non-linear cross-sectional estimation as in Hall et al (2000), but carry out a fixed-effects estimation as well.

3 Data

This data set was generated using information from different sources. To the best of the authors' knowledge, this is the first data record of this nature for Germany which combines annual financial statements prepared according to national and international accounting standards with stock market and patent data.

3.1 Accounting data

The Hoppenstedt firm database is a commercial database providing detailed annual financial statements for firms accounting in accordance with HGB, IAS or US-GAAP. The firms selected for the analysis fulfil the following criteria:

- Consolidated financial statements available
- Operating in manufacturing industry, data processing and/or providing business services
- Availability of market information (prices and volume of securities)

These selection criteria yield 540 firms with 2,331 observations for the period from 1997 to 2002. 903 annual financial statements (38.8%) were prepared in accordance with international accounting standards (IAS or US-GAAP). Given that the sub-samples for financial statements prepared in accordance with IAS and US-GAAP were too small for a multivariate analysis, they were considered together and are therefore denoted below as international financial statements.

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[34] To structurally interpret coefficients $\left(\beta_1 - \beta_1^0\right)$, $\left(\beta_2 - \beta_2^0\right)$ and $\left(\beta_3 - \beta_3^0\right)$ from Equation 6, one would have to theoretically assume a multiplicative link between different intangible fixed assets reported by national or international accounting standards, and from patent information in Equation 1. This does not appear realistic. The result from Equation 6 can only be assessed by statistical comparison. The construction of an estimation reflecting the iteratively separable character of potentially different intangible fixed assets at firm level (Braindard/Tobin, 1968) is not trivial.

3.2 Stock market data

Stock market prices and the volume of securities were derived from data supplied by Karlsruher Kapitalmarkt Datenbank (KKMDB),[35] Datastream, and the Hoppenstedt stock guide (1999, 2000, 2001 and 2002). Market information on 540 firms was collated in accordance with the parameters set by the Hoppenstedt corporate database. The stock prices on the last trading day of the calendar year were used.[36] The face values[37] and associated adjustment factors were included in the calculations of the number of securities. A firm's market value is the product of the adjusted share price and the number of securities.

3.3 Patent data

European patent data were extracted for the samples of firms.[38] The data source used was the official Online European Patent Register of the European Patent Office (EPO) www.epoline.org. Data were extracted in November/December 2003, so that all the firms' patent applications up to May/June 2002 were included.[39] For the purpose of identifying relevant patents/patent applications, firm names were fragmented as individually and as clearly as possible. Before the matching with balance sheet and stock market data, the database was checked for accuracy through time-consuming manual consolidation. The extraction yielded an absolute figure of 124,738 European patent applications[40] by the firms in question from 1978 to 2002. During this period a total of 235 of the firms in the sample filed patents with the EPO.

3.4 Generating the variables

The value of a firm i at time t is derived from the market value of shareholders' equity, which is defined as the product of the number of shares and the share price, plus the

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[35] Data from the Karlsruher Kapitalmarkt database are available for research purposes only. Compare http://finance.wiwi.uni-karlsruhe.de/Forschung/kkmdb.html

[36] Compare section 3.4 on the problems of the signalling effect of balance sheet data on market values (and vice versa).

[37] The introduction of the Euro prompted many firms to redenominate the face value of their shares.

[38] Since the sample comprises solely listed firms, it seemed more appropriate to select European rather than German patent data. This logic is based on the assumption that German listed firms usually tend to operate in product markets across Europe and are therefore interested mainly in international patent protection. The selection of one source of patent information only is due to a simple budgetary constraint.

[39] European patent applications are published after an 18-month disclosure period (see above).

carrying amount of the liabilities. Since the balance sheet information relates to the reporting date of 31 December of a given year, the market prices for the last trading day of the year were used. As a rule, annual accounts are published during the first quarter after the reporting date. Since no information is available on the exact dates and since we are interested in the correlation on the reporting date, this procedure appears quite reasonable.[41] Tobin's q is calculated as the quotient of market values and tangible fixed assets (capital stock).

Capital stock variables for tangible and intangible fixed assets at the respective replacement cost are required to test the hypotheses. The three accounting standards HGB, IAS and US-GAAP calculate these variables from the schedule of fixed asset movements according to the perpetual inventory method. The capital stock of the intangible fixed assets is calculated differently for financial statements prepared in accordance with national and international standards. While financial statements prepared in accordance with HGB include only concessions, acquired patents and licences, international accounting standards also include the development costs of the intangible capitalised capital stock (though not expected profits, see above). Inventories are also included in the calculation at historical acquisition costs. In line with the approach adopted by other studies, R&D expenditure in the P&L was also included in addition to the variables from the balance sheet. These details provide on the one hand the flow variable for R&D expenditure and on the other an R&D stock variable which is derived from the sum of expenditure less a depreciation rate. Given that during the sample period, some firms changed their accounting practices from national to international accounting standards,[42] relevant indicator variables were declared, identifying the accounting standard for the financial statements for each individual observation.

Similar to the information on accounting standards, patent information was calculated at group-level, ie patents from subsidiaries were added to parent company

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[40] This is understood as the number of European patent families, where one family can include additional overreaching countries (4) in addition to the European member states (27).

[41] For the remainder of the project, market prices at different points in time are to be included in the calculation of market values. This will allow testing, for example, of option pricing models.

[42] 127 firms changed from HGB to IAS, 58 from HGB to US-GAAP and 7 from IAS to US-GAAP.

patents. A total of four different patent stocks were calculated, which were tested alternatively in the multivariate specifications, two traditional and two new variables.

To create the first variable (PATCLASS1), European patent applications[43] were aggregated at group-year level and the stock variable for a year t was calculated as a cumulative variable from the year 1978 to t.[44] As in Hall et al (2000) the patents were discounted by 15% per annum in order to model the loss in value of technology over time. While this type of discounting is justified especially considering the patent stock as a key variable for a firm's cumulative intellect (the percentage decline in this value remains constant over time), it can be argued on the other hand that industry-specific product cycles may have more complex evolutions[45] than specified by the exponentially falling discount function.

Taking recourse to the central concepts of Pakes' (1986) pioneering research, we therefore also calculate an additional patent stock variable (PATNEW1) which discounts the patent (family's) value to zero, as long as it is not renewed any further (ie the technology is made publicly available).[46] There is no additional discounting of the patent value over time. Given the fact that European patents are classified in a group of national patents after they are granted the renewal decisions can only be understood on a national level.[47] Consequently, unlike the PATCLASS1 variable, the PATNEW1 variable is based as an analysis unit on national patents in the member states (disaggregated) and not on the entire European patent family (aggregated).

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[43] The granting of patents by the EPO can take several years. The literature states an average of 4.3 years for the biotechnology and pharmaceutical industries. Since our sample period lies in the recent past and we are particularly interested in including the firms' patenting activities during this period (1997 to 2002), we therefore resort to applications and not to patents granted. The fact that patent applications are on average less valuable than patents granted (Guellec and vanPottelsberghe, 2000) is taken into consideration in the following interpretation of the results.

[44] NB: For 2002, we only had patent applications up until the end of April 2002, due to the 18-month disclosure period up to the data collection date (November 2003). The patent stock for 2002 must thus be corrected. Assuming patent application numbers for the second half of the year can be extrapolated from the number of applications for the first 5 months of 2002, the real patent stock for 2002 was multiplied by 12/5.

[45] Compare e.g. Kotler and Bliemel (1995).

[46] We are aware of the fact that Pakes' original paper (1986) which considers the decisions on extending patents has a different premise and pursues a different methodology. Hence, if we refer to a "recourse", this of course relates only to utilising publicly available renewal decisions.

[47] Note: to the best of the authors' knowledge, the national patent offices provide information on patent extension to the EPO at their discretion. One can also assume that the extension information on the individual member states found on www.epoline.org is incomplete. We were unable to redress the issue of the inadequate data in this version of the article.

PATCLASS2 differs from PATCLASS 1 in that the variable weights the patent stock in terms of quality. Based on the papers of Hall et al (2000) and Bloom and van Reenen (2000), we assume that quality-weighted rather than non-weighted stock variables offer better opportunities for operationalising a firm's intangible fixed assets. However, given that our firm data record comprises the period from 1997 to 2002 and a large proportion (approx. 30%) of our patent applications are thus only five to six years old, we refrained from weighting the patents using forward citations.[48] Similar to Lanjouw and Schankerman (1999), we create a central quality index from procedural indicators available already in their preliminary form after publication of the patent application (see Reitzig, 2002). For this purpose, the backwards citations (see also Breitzmann and Thomas, 2002) of the European or international search (for PCT applications) on patent and non-patent literature[49], the family size (only for PATCLASS1 and PATCLASS2), and a dummy variable for global application (PCT) are factorised, and the patent application is weighted by these three variables multiplied by their eigenvalues from the factor analysis. The difference between PATNEW2 and PATNEW1 is, after all, similar to that between PATCLASS2 and PATCLASS1.

4 Empirical results

4.1 Descriptive statistics

In Germany in the early 1990s, all market segments were characterised by major share price increases. However, we saw dramatic price corrections towards the end of the 1990s, resulting in a considerable fall in the market value of listed firms. Thus, overall, the period provides an illustration of the initial grow and eventual blow of a bubble. Figure 1 shows the average market values of firms in the sample and illustrates the development during the sample period.

[48] Note: Hall et al (2002) describe how to approximate the number of expected forward citations for young patents. As a rule, we could have pursued this approach in this article as well. However, we deliberately refrained from the core variable whose practical applicability for the valuation of young patents is not unproblematic (see also Reitzig 2002).

[49] Minor adjustments of the variable (alternative declarations) are anticipated in future versions of this paper.

Decomposing the sample into the different accounting systems shows that the market value of firms reporting in according with international standards tends to be higher than firms reporting according to HGB.[50] It should, however, be noted that the variance of firms following international accounting practice is considerably higher. Furthermore, market entries and exits, and changes in the accounting regime alter the respective sample size.

Figure 1. Average market values in accordance with accounting standards

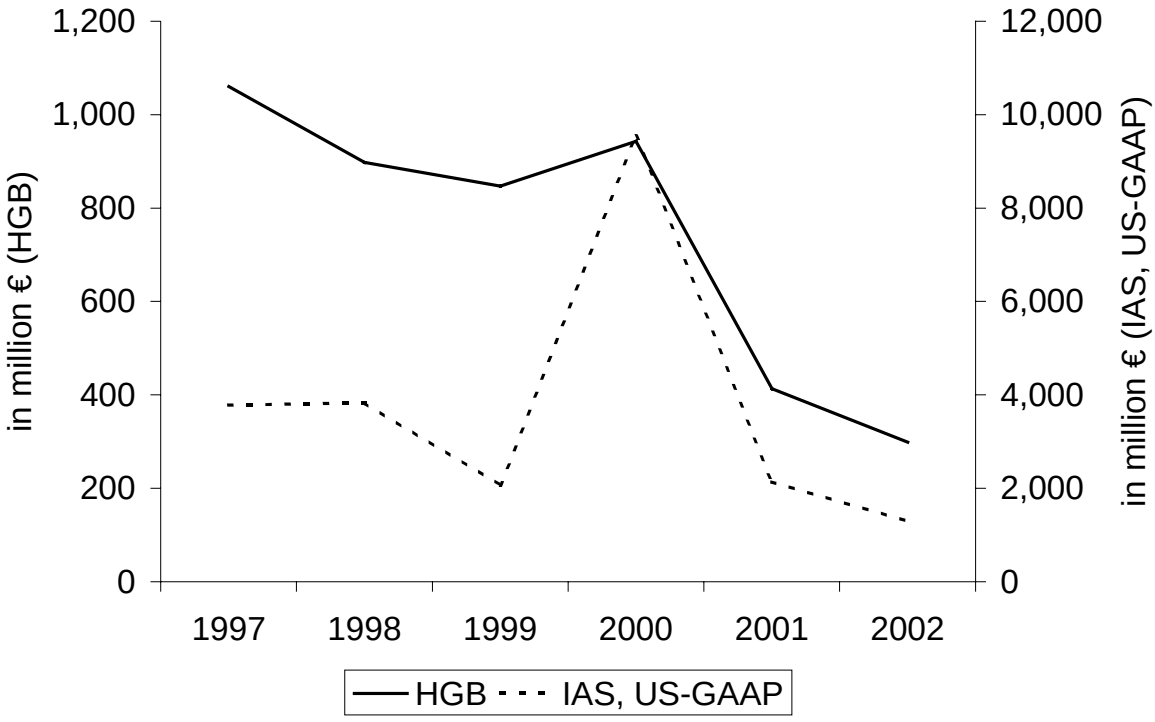


Figure 2 illustrates the average development over time of the balance sheet variables used in the multivariate analysis. In line with expectations, the level of intangible fixed assets – measured as the sum of licences and capitalised own work at replacement cost – fell only marginally based on HGB. On the other hand, intangible

[50] At first sight, this observation could hint at a selection bias in that certain types of firms prefer particular accounting standards. At second sight, however, we deem the problem less grave as certain market segments provide for the application of particular accounting standards (see above). These segment specific effects, however, should already be captured by the fixed effect estimation at firm level.

fixed assets of firms reporting in accordance with international accounting standards rose significantly throughout the sample period. It must also be stated here that the sample composition had changed. R&D expenditure and R&D capital stock showed a comparatively similar evolution to that of intangible fixed assets in accordance with international accounting standards.

Figure 2. Average values of the explanatory variables (level variables)

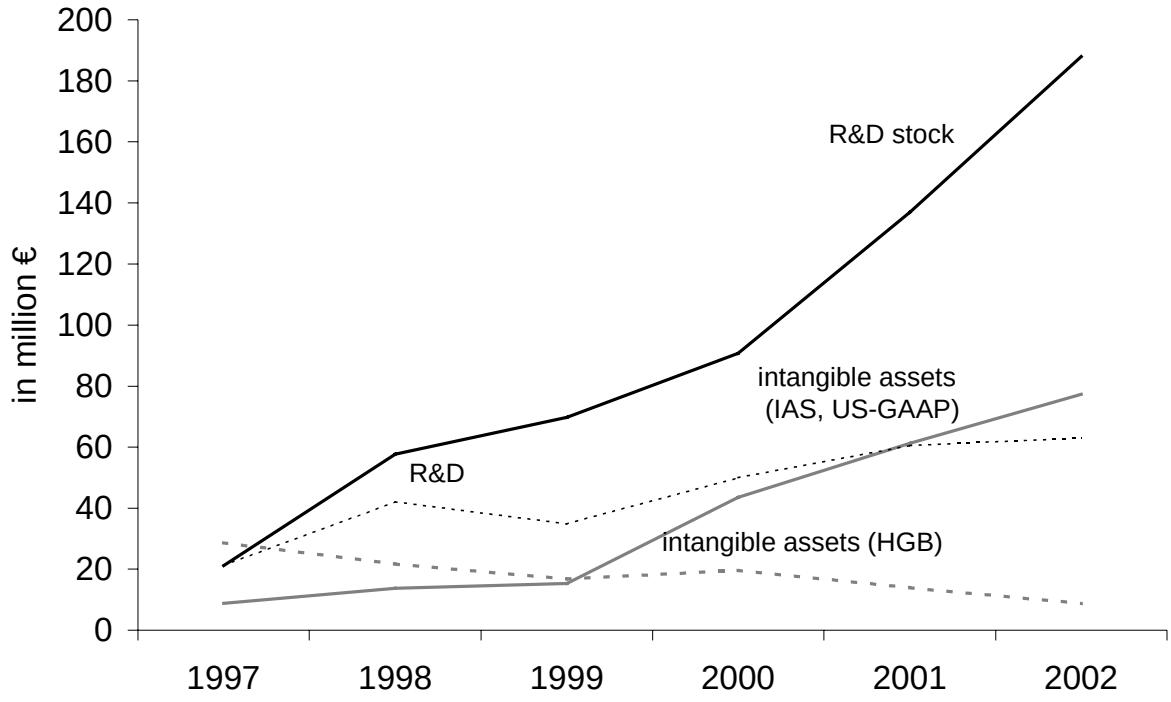


Table 1 provides a detailed description of the data record used and illustrates the comparatively high level of data heterogeneity. In contrast to other empirical analyses, the extremely high ratio of the market value to tangible fixed assets (fundamental value) is particularly conspicuous. Averaging 2, the ratio of intangible fixed assets to fixed assets is very high, in particular, for firms reporting in accordance with international accounting standards. With the share of licences and capitalised own work averaging 0.7 (IAS and US-GAAP) and 0.2 (HGB), one can assume the financial resources available were used for take-overs of (other participating interests in) firms. The accounting problems related to goodwill already discussed in Section 2.2, and the descriptive analysis provide indicators for dealing critically with this variable. In the

multivariate analysis, therefore, the licences and capitalised own work were used as explanatory variables. Nevertheless, the results at hand also show that the q-model approach, too, should be re-evaluated in that intangible fixed assets should also be included in the fundamental value.

Table 1. Descriptive statistics (total sample)

	Obs.	Mean	St.dev.	Median	Lower percentile	Upper percentile
Market value / tangible assets	2.221	120.4146	3808.922	2.3608	0.3645	610.1508
Intangible assets / tangible assets (HGB)	1.428	0.6565	3.3561	0.0829	0	15.2949
C+cO[1] / tangible assets (HGB)	1.428	0.2560	2.2887	0.0351	0	3.8421
Intangible assets / Assets (IAS, US-GAAP)	903	2.0440	4.1187	0.5637	0	20.9531
C+cO[1] / tangible assets (IAS, US-GAAP)	903	0.7236	2.3387	0.1272	0	9.3417
R&D expenditure / tangible assets (IAS, US-GAAP)	903	0.2455	0.6414	0	0	2.8940
R&D stock/ tangible assets (IAS, US-GAAP)	903	0.4430	1.2821	0	0	5.0128
Patclass1 / tangible assets	1.139	0.1358	0.3556	0.0357	0	1.9733
Patclass2 / tangible assets	1.139	0.5267	1.5524	0.1098	0	8.8888
Patnew1 / tangible assets	1.139	0.2545	0.6724	0.0694	0	3.8918
Patnew2 / tangible assets	1.139	0.2755	0.8357	0.0718	0	4.0527

[1]C+cO: concessions and capitalised own work

The following observations can be made with respect to the patent variables. During the sample period, a total of 124,738 European patent applications were submitted by the firms in the sample. On average, the European patent family extends over approx. nine states, and an average of 3.8 patent references and 0.7 non-patent references are cited as the state of the art.[51] Approx. 24% of all patents were registered with the EPO within the scope of the Patent Cooperation Treaty (PCT). To form the quality index required to create the PATCLASS2 variable, the variables for patent family size, references to patent and non-patent literature and the PCT dummy variable

[51] Our indicators are based on European research. References from the international search are also taken into consideration for PCT applications. Given the distribution by industry, the mean values appear plausible. The values for non-patent citations are systematically below Harhoff and Reitzig (2004), although they analyse the highly science-oriented biotechnology and pharmaceutical industries in their research.

were factorised, resulting in eigenvalues of approximately zero for the references to patent and non-patent literature, 0.31 for family size and 0.34 for the PCT indicator. To create the PATNEW1 and PATNEW2 variables, the European patent families were initially disaggregated to individual patent level. A second factor analysis to create the quality index for PATNEW2 excluded the family size for the remaining three quality variables (references to patent and non-patent literature, PCT dummy). This resulted in eigenvalues of 0.23 for patent citations, 0.9 for non-patent citations and 0.19 for the PCT dummy.

Before it is multiplied by its average cash value in Euro (see below), the simplest patent stock variable (PATCLASS1), which reflects the cumulative patent stock at group level for the respective year, has a mean value of approx. 52 for the entire sample and approx. 86 for the group of those firms actually granted a patent.[52] The corresponding mean values for the quality-weighted stock of registered European patent families (PATCLASS2) in the groups described are approx. 136 and 227. On account of the exclusively positive eigenvalues of the corresponding factor analysis and the positive attributes of the variable for family size and the PCT dummy, the higher mean values for PATCLASS2 compared with PATCLASS1 are in line with expectations.

PATNEW1 has a mean value of approx. 780 in the group of all firms and 1,309 in the sub-group of firms that have actually been granted patents. These figures can be interpreted graphically in that they specify the cumulative patent stocks at individual patent level per firm, from which only the individual patents registered in the respective year in the individual member states are subtracted for "discounting purposes". PATNEW2 has mean values of 759 and 1,278 in the aforementioned groups, which is slightly lower than the mean values of the non-quality-weighted patent stock. Given the strong similarity between the distributions of the PATNEW1 and PATNEW2 variables, it can be confirmed that the quality weighting using backwards citations and the PCT dummy at individual patent level is negligible overall.

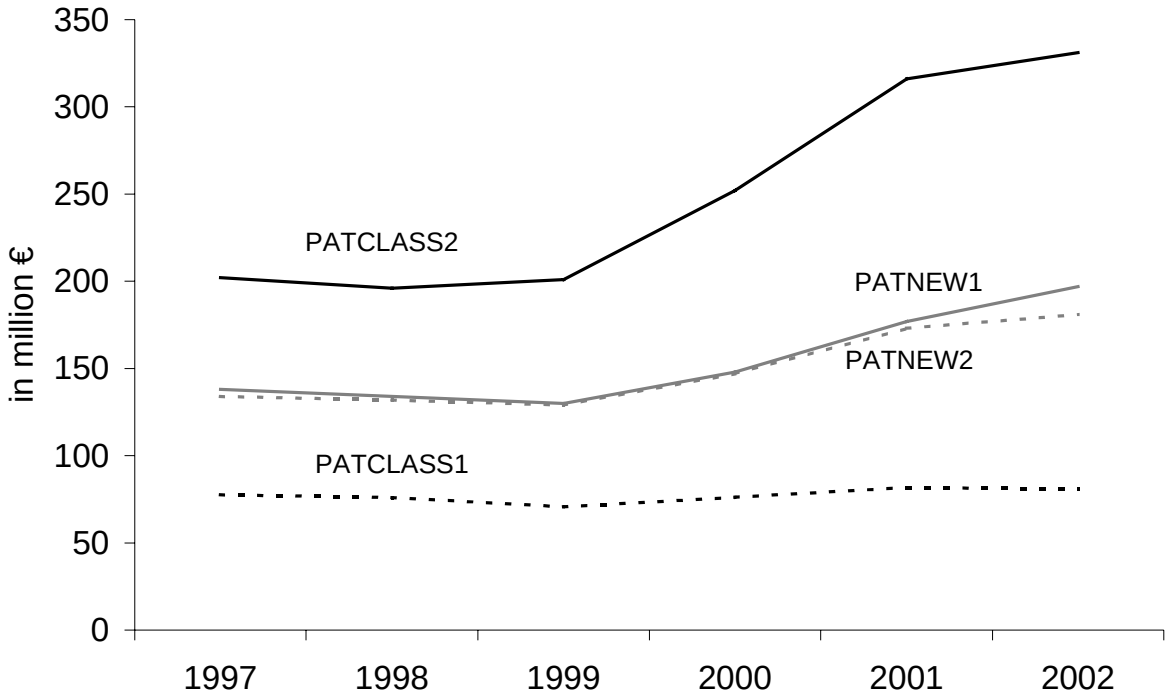
To facilitate a better comparison of the coefficients for the patent variables and the balance sheet variables measured in Euro for the following multivariate analysis, the patent variables were multiplied by an average value per patent (see above). EUR

[52] It is difficult to illustrate this variable after annual discounting and cumulation.

500,000 was allocated to a European patent family (PATCLASS1, PATCLASS2) and EUR 50,000 or one-tenth of the value, to an individual country patent.[53] On the basis of these assumptions, it can be ascertained that the average (expected) net return associated with the patents lies between EUR 77 million and EUR 256 million (depending on the patent stock variable created) in the group of firms actually filing for patents.

Remarkably, the patent stock variables also increased in value during the sample period. They are similar in this respect to the other "exogenous" variables (R&D stock, intangible fixed assets), although the rise in the patent variables over time is lower. Figure 3 shows the correlation:

Figure 3. Average values of the patent variables



[53] These figures represent no final solution to the quantification problem of expected returns from patents. They are much more a reflection of a reasonable cross-industry approximation based on the estimates found by recent studies, for example, Harhoff et al. (1999) and Reitzig (2004).

4.2 Multivariate analysis

The multivariate analysis is divided into two main sections, in which the data are initially interpreted as pooled cross-sectional data and subsequently as panel data. Based on Equation (2), we initially estimate the q-model as pooled and non-linear using a full set of time dummies. Our approach is therefore comparable to that of Hall et al (2000). A disadvantage of this approach is the assumption of an identical error term for all firms i. Still, the estimation can provide initial indications of systematic correlations and can be used as a comparison to the work of Hall et al (2000). The results are shown in Table 2 in line with the derivation of the hypotheses in 2.4.[54]

The explanatory variables which measure the capital stock of the intangible fixed assets are replaced sequentially in Columns 2.I to 2.VIII, as per the objective of the article, with the capital stock being defined as the sum of licences and capitalised own work. Columns V through VIII are subdivided and present estimation results for the patent variables on two different sub-samples. Namely, these sub-samples are the 'national' and the 'international' sub-sample, depending on whether corporations would adopt HGB or IAS/US-GAAP. The subdivision is a prerequisite to compare the results for the patent variables with the different balance sheet data (models 2.I and 2.II).

Overall, all explanatory variables turn out to be significantly positive. The coefficients from Model 2.I and 2.II can be compared on the basis of the following test.[55]

$$\frac{\hat{\beta}_1 - \hat{\beta}_2}{\sqrt{Var(\hat{\beta}_1) - Var(\hat{\beta}_2)}} \approx N(0,1) \tag{7}$$

The comparison of the coefficients using estimates 2.III and 2.IV, and 2.V to 2.VIII is drawn on the basis of the t-statistics. While Columns 2.I to 2.VIII allow a structural interpretation of the estimated parameters, the results from 2.IX to 2.XII serve to identify possible differences between the accounting standards and the analysis of the additional explanatory power supplied by the patent variables concerning the R&D

[54] All results are generated from different outlier adjustments in which the upper and lower 1% percentile for all variables is disregarded. Furthermore, only firms with at least three consecutive observations after the outlier adjustment are included in the respective sub-samples.

variables. The results of the test statistic from Equation 7 (for the Column I and Column II) and the results from Column 2.IX provide first indications of possible differences in the accounting procedures. The normally distributed test statistic has a value of 8.04, which indicates positively significant differences between the accounting standards. Another pointer was the estimation from Column 2.X, where both the combined variable from both national and international accounting, and the indicator variable for the change in the accounting regime were significantly positive – consequently, the test for parity of both capital stock variables can be rejected at the 1% level. Both are indications of considerable differences with respect to the sign and the size of the effect between the different accounting standards.

The results in Columns 2.X to 2.XII are generated by including additional variables for intangible fixed assets in Equation 2. The assumption behind this implies the variables capturing the firm's intangible fixed assets are not correlated. Differences in the results from Column 2.X compared with Column 2.I concerning the capital stock variables are insignificant. The patent variable PATNEW1[56] is positively significant and provides additional explanatory power (compare the R2 values between 2.I and 2.X). The results from Estimates 2.XI and 2.XII show that the patent variables do not provide any additional explanatory power in the international sample, whereas the variable R&D expenditures is positively significant and results in a higher R2. This accords only partly with the results of Hall et al (2000). However, there obviously is a correlation between the intangible capital stock calculated in accordance with international accounting standards and both R&D variables, which show up in smaller estimated parameters.

A major criticism of the pooled estimation is that firm-specific effects are possibly not taken into consideration, so that the estimations in Table 2 are distorted. Equation 6 was therefore estimated in accordance with the derivation in Section 2.5. First, we use a random-effects approach. However, both the Breusch-Pagan test and the Hausman test supply unambiguous test statistics which indicate the presence of fixed effects. For that reason and owing to the theoretical consideration that investors do not use balance sheet

[55] This test applies to independent sub-samples.
[56] As the test statistics of the patent variables supply nearly identical results, the variable PATNEW1 was selected on grounds of comparability with results from Table 3.

and patent information without looking at fixed firm effects, we use a fixed-effects approach (within estimator) as a second step.[57] Table 3 contains the results of this analysis, with the same structure being applied as in Table 2.

Except for the intangible capital stock calculated in accordance with international accounting standards and the PATNEW1 and the PATNEW2 variables calculated for the sample of firms accounting in accordance with the HGB standard, all variables in Columns 3.I to 3.VIII are insignificant. The intangible capital stock calculated in accordance with international accounting standards shows a weakly significant and negative sign. The results thus show considerable differences from the pooled estimation in some cases (Table 2). The finding indicates a correlation between the variables and the fixed effect. Both the test statistic (Equation 7) between Columns 3.I and 3.II with value 1.68 and the direct test for parity of the coefficients in Column 3.IX point towards considerable differences between national and international accounting standards.

For the estimations in Columns 3.X to 3.XII, the PATNEW1 variable was chosen as the optimum patent variable based on the t-statistics (Columns 3.V-3.VIII). In Models 3.X, 3.XI, and 3.XII, which are difficult to interpret from a structural perspective, the coefficients for the intangible assets remain insignificant in the national sample and negatively significant in the international sample. It is only in the partial sample of national accounting that the patent variable provides a positive coefficient. The R&D expenditure variable provides no additional explanatory power. The change in the accounting regime, on the other hand, is insignificant throughout.

[57] We use the heteroscedasticity robust estimator suggested by Arellano (2003). As mentioned earlier, we unfortunately do not find any suitable instruments for the variables when estimating GMM.

Table 2. Results of non-linear estimation (standard error in brackets)

	2.I	2.II	2.III	2.IV	2.V	2.VI	2.VII	2.VIII	2.IX	2.X	2.XI	2.XII
L&cO[1]	10.19								11.26	9.98		
(HGB)	(1.13)***								(1.47)***	(1.11)***		
L&cO[1]		1.37							1.18		1.26	0.81
(IAS, US-GAAP)		(0.30)***							(0.20)***		(0.29)***	(0.21)***
R&D exp.			1.84									0.52
(IAS, US-GAAP)			(0.39)***									0.08)***
R&D stock				0.78								
(IAS, US-GAAP)				(0.19)***								
Patclass1/2 Patnew1/2					1.08	0.32	0.51	0.49		0.31	0.14	0.12
national sample					(0.31)***	(0.09)***	(0.16)***	(0.15)***		(0.11)***	(0.15)	(0.14)
					1.14	0.27	0.54	0.44				
international sample					(0.56)**	(0.13)**	(0.27)**	(0.22)**				
Accounting dummy									1.43			
									(0.08)***			
Number of obs.	1213				1213	1213	1213	1213	1964	1213		
		608	608	608	608	608	608	608			608	608
R-square	0.25				0.03	0.03	0.03	0.03	0.34	0.26		
		0.19	0.21	0.18	0.13	0.13	0.13	0.13			0.19	0.24

All regressions are estimated using a full set of time dummies

[1] L&cO: licences and capitalised own work

[2] R&D: expenditure for research and development

* significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level

Table 3. Results of linearised fixed-effects estimation (robust standard error in brackets)

	3.I	3.II	3.III	3.IV	3.V	3.VI	3.VII	3.VIII	3.IX	3.X	3.XI	3.XII
L&cO[1]	0.59								0.08	0.58		
(HGB)	(0.40)								(0.19)	(0.37)		
L&cO[1]		-0.08							-0.19		-0.08	-0.12
(IAS, US-GAAP)		(0.04)**							(0.02)***		(0.03)**	(0.02)***
R&D exp.			0.86									0.61
(IAS, US-GAAP)			(0.58)									(0.84)
R&D stock				0.05								
(IAS, US-GAAP)				(0.14)								
Patclass1/2 Patnew1/2					1.77	0.15	2.65	3.44		2.64	3.72	3.57
national sample					(1.61)	(0.17)	(1.34)**	(0.80)*		(1.33)**	(4.01)	(2.91)
					5.20	1.16	3.57	3.53				
international sample					(6.61)	(1.33)	(4.15)	(3.73)				
Accounting dummy									-0.03			
									(0.07)			
Number of obs.	1213				1213	1196	1213	1213	1957	1213		
		608	608	608	608	660	608	608			608	608
Number of firms	244				244	240	244	244	414	244		
		167	167	167	167	178	167	167			167	167
R-square	0.10				0.10	0.10	0.12	0.11	0.30	0.12		
		0.45	0.46	0.46	0.45	0.45	0.46	0.45			0.47	0.49

All regressions are estimated using a full set of time dummies

[1] L&cO: licences and capitalised own work

[2] R&D: expenditure for research and development

* significant at the 10% level; ** significant at the 5% level; *** significant at the 1% level

5 Discussion

The hypotheses derived in 2.4 are discussed below on the basis of the results from the fixed-effects estimation in Table 3. We would like to emphasise again that the analysis is based on the situation specific to the sample period. The reported findings from the descriptive analysis illustrate in particular the initial euphoria and eventual delusion experienced in all German market segments in the 1990s.

Even the description of the data shows that market values clearly exceeded firms' fundamental values, particularly in the middle of this period. At first sight, however, it does not allow a differentiated discussion of the anticipated correlations from Hypotheses 1-5. In particular, a glance at Figures 1 to 3 suggests that neither balance sheet information nor patent information are correlated with the firms' market values. While the market values first grew and then collapsed dramatically in some cases over the sample period, the mean values of all 'exogenous' variables rose rather constantly over time. However, the results of the multivariate analysis reflect the correlations in question more precisely.

On the basis of our analyses, we confirm our first hypothesis which negates a correlation between intangible fixed assets reported in accordance with HGB and the residual market value calculated by a q-model. The parameter determined in Column 3.I proves insignificant during the volatile market period chosen. The prudent approach to valuing assets, which is mirrored especially in the strict principle of lower of cost or market, hence seems unsuitable from an outside investor perspective.

Coming to our second hypothesis, we find no empirical evidence for a positive correlation between intangible fixed assets reported in accordance with IAS or US-GAAP and q. The coefficient is significant at the 10% level but is inconsistent with the hypothesis as it has a negative sign. Consequently, our study does not confirm the argument frequently cited by the proponents of international accounting standards that financial accounts prepared in accordance with IAS or US-GAAP are more informative than cautious German standards. Although it is true that Estimation 3.II shows a better fit than Estimation 3.I, this alone is insufficient to consider information reported according to international accounting standards valuable for investors (see also Lev and Sougiannis, 1996). Even proponents of international accounting did not assume ex ante

that the correlation between intangible fixed assets reported in accordance with IAS or US GAAP and the firm's residual market value should be negative. Moreover, the high goodness of fit is mainly due to the constant and the time dummies of Model 3.II alone. Hence, our result is counter-intuitive and therefore calls for explanation.

Observing the data in more detail offers various potential and partly opposed explanations. The first explanation takes up the argument by Lev and Sougiannis (1996) that capitalising only one side of the coin – namely expenses – leads to distractions in information value unless they are contrasted with expected returns (direct investor interpretation). However, it may as well be possible that investors view capitalised expenses as an indicator of expected returns (indirect investor interpretation). In this second case, two further considerations can buttress the empirical findings. Firstly, explicit cases are reported when firms near the verge of bankruptcy commenced capitalising all sorts of intellectual property related expenses in a desperate final attempt to signal their anticipated mid-term returns to investors – deposing the accounting information of its actual meaning. Secondly (and in line with the previous consideration) we find that the majority of observations for internationally accounting firms in the present sample stems from the period between 1999 and 2002. Overall, this period shows a decline in the firm values, hence, the negative correlation between the intangibles as reported in accordance with IAS/US-GAAP and the firm values indicates that the balance sheets tend to overvalue the firms with respect to intellectual property. This finding appears plausible ex-post along two dimensions. On the one hand, the firms' high valuation during the beginning and middle of the sample period obviously gave access to financing sources that were not used entirely for investment in tangible fixed assets. The steep increases in the value of intangible fixed assets are indicative of the investments in this category of fixed assets[58] (see Table 1). It must be assumed, however, that the licences acquired were often overpriced (this brings to mind EM TV). Whilst market participants reacted to the revelation of overvaluations by price markdowns, there was no corresponding write-down of the overvalued balance sheet items.

[58] Bond and Cummins (2000) interpret high growth rates of *q* as typical for the New Economy.

In theory, the last of the two previous arguments adopted to explain the findings in 3.II. (overpricing of acquired licences) could manifest itself similarly in the firm's patent stock variables, especially if the expected return on firm-internal innovations was overestimated. Interestingly, with an eye on Hypothesis 3, however, estimations 3.V – 3.VIII show that the PATNEW1 and PATNEW2 variables are significantly positively correlated with q, at least within the sample of firms accounting in accordance with national German standards. Thus, apparently, marking close to market does not per se exclude compliance with cautious accounting principles. As long as envisaged output is validly assessed (for example, through patent data), it may provide relevant information to outside investors at low risk of misinformation.[59] A stock variable at country level with a constant depreciation rate provides the best results with respect to the test statistics, the plausibility of which was theoretically grounded (see above). A constant depreciation rate apparently represents a less realistic fall in the value of the technology than does depreciation, which is solely restricted to patent expirations in individual member states. Unexpectedly, there is no value added in quality weighting the patent data variable with classical procedural indicators (PATNEW2) when comparing it with the purely quantitative data (PATNEW1). This finding is somewhat inconsistent with the earlier studies mentioned and may be attributed to the relatively limited power of EP backward references to reflect patent quality compared with US backwards references.

Looking at Hypothesis H4, both the test statistic (cf. Equation 7) and the results from Model 3.IX show significant differences between national and international accounting practices with respect to the influence on q. In model IX the HGB coefficient calculated for the capital stock remains insignificant when both accounting parameters are estimated simultaneously.[60] By contrast, a significantly negative parameter is estimated for international accounting. Hence within the framework of a common estimation with national annual financial statements, international accounting provides more information (albeit negative) for q. However, the key question (see discussion on H2 above) remains how plausible this information is ex-ante, and thus to

[59] That said, however, it must be acknowledged that the patent variables have insignificant coefficients when tested on the sample of firms accounting according to international standards, regardless of the construction of the variable. This finding clearly indicates that selection distortions and the small number of firms in the international sample limit the overall interpretability of the international sample compared to the national sample.

[60] This approach corresponds to estimation with interaction terms for accounting.

what extent international accounting can be recommended as a source of information for investors.

Models 3.IX to 3.XII serve to test Hypothesis H5. This gives rise to somewhat more complex discussion since the estimation results can no longer be interpreted simply from a structural perspective. To interpret the variables for intangible fixed capital stocks structurally, the variables would need to have a substitutional character and (in line with Equation 6) the coefficients would have to be deemed to have multiplicative links. However, such an interpretation would imply a negative sign for the entire capital stock in line with the results from 3.IX. This would appear to be counter-inductive. Quite obviously, the assumptions for structural interpretability within the scope of this sample are not sufficiently met. In the following, therefore, the estimation results of Models 3.IX to 3.XII are mainly interpreted on a comparative statistical basis and less importance is attributed to Equation 6 with a view to testing the robustness of the findings.

Columns 3.X, 3.XI and 3.XII show the results of the fixed-effects estimation for the two sub-samples separately. Model 3.X shows virtually no change in the coefficient for national accounting and the patent stock with regard to the size of effect and significance compared with Models 3.I. and 3.VII. (national sample). The findings indicate, however, that the patent stock and intangible fixed assets reported in accordance with HGB add up slightly when explaining firms' values. Given the different information contents of the two variables, the finding is not surprising. Also, if the intangible capital stock is simultaneously modelled on international accounting and the patent stock (3.XI), both the effect size and (in)significance of the individual coefficients stay almost constant and the overall fit of the estimation increases slightly compared with Model 3.II. The finding points at low level of correlation between the intangible assets as reported according to international standards and the patent variable that is in deed confirmed when looking at the covariance matrix (Pearson coefficient equals 0.06). The positive change in the goodness of fit going from 3.II to 3.XI implies a weak though additive relationship between the two variables regarding their explanatory power for the firms' residual market values. However, given the ex ante unexpected sign of the coefficient for the intangibles assets reported in accordance with

US GAAP/IAS and the insignificant patent variable in specification 3.XI, we do not think that the data provide preliminary empirical evidence for H5.

6 Summary and outlook

Taking the growing internationalisation of accounting practices in Germany as an example, this paper examined two fundamental issues. The first question focused on whether accounting information derived from international reporting standards (IAS and US-GAAP) allowing for the activation of development expenses offers a more realistic (i.e. more market-conform) picture of a firm's intangible fixed assets than its German HGB counterpart prohibiting any capitalisation of in-house R&D. The second question focused on the usefulness of including publicly available patent information in annual financial statements.

In answering these questions, the paper presented a theoretical and empirical analysis. The theoretical analysis showed that for outside investors, who are becoming increasingly significant as providers of capital in Germany, international accounting standards should be more attractive than their German counterparts, since the former allow expected return from own intellectual property to be capitalised. The analysis also pointed out that, at least from an international accounting perspective, patent information might be suitable for illustrating a firm's intangible assets as it provides relevant information and comes at a relatively low management/investor agency risk.

The empirical analysis supplied a first empirical test of the anticipated correlations. Based on a comparatively large sample of listed manufacturing firms from 1997 to 2002, and the respective market, balance sheet and (European) patent data, the empirical analysis presented a far more differentiated, albeit incomplete, view of the theory. During the sample period, which was characterised especially by an initial increase and final share price collapse (grow and blow of a bubble) in Germany, the national accounting standards provided no explanatory contribution for the residual market value of the firms, while international accounting showed a negative correlation with the residual value. The analyses indicate that during the selected "critical" period the prudent approach to valuation, mirrored in particular in the strict principle of lower of cost or market, is 'useless but harmless' for outside investors, whereas international

development costs capitalization either makes firms look worse off than they are (direct investor interpretation) or illustrates firms' funding surplus which is not offset by any value-adding investments (indirect investor interpretation). As such, international accounting standards contain ex ante misinformation regarding intangibles and may actually have an effect on investor enlightenment that is opposite to the one intended. Patent information, on the other hand, appears to provide a plausible (positive) explanatory content ex ante on the firms' residual value which – as expected – complements the prudent HGB information. Notably, a patent variable constructed at the individual country level that is 'depreciated' only when the underlying invention is lapsed into the public domain proves the most powerful.

We would like to emphasise once again the limitations of the interpretability of our results. In particular, we are aware of the fact that the samples of the firms reporting in accordance with international accounting standards or HGB are not identical. We also admit that it is open to discussion whether balance sheet and patent information have a partial signalling effect on market value, thus evidencing problems of endogeneity, or whether dynamics are involved which we do not capture in the simple q-model. As always, the shortcomings of the present paper concurrently open up research fields for future papers. The approach of Bond and Cummins (2000), which recommends a new definition of the fundamental value, could represent a promising variant for further research for the data record at hand.

Nonetheless, we believe that our paper makes an important contribution. To the best of our knowledge, it the first large-scale empirical study of its kind for Germany, and concerning the comparability of different balance sheet information worldwide. Despite its shortcomings, it implicitly offers clear recommendations for legislators. First, they need to consider whether to favour a fully prudent accounting regime for intangibles in which neither expenses nor expected profits may be capitalised, or whether they allow the capitalization of expenses. This analysis, as Lev and Zarowin (1999) points at the problems of permitting capitalisation of expenses but prohibiting the capitalization of expected returns at the same time. Regardless of the contractual efficiency of such a standard, signals may be distorted for investors and overall information efficiency is reduced. Thus, if (R&)D expenses are capitalized it might be useful to put up the capitalisation of their expected returns for revision. One relevant

source of information for corporations working in high-technology sectors is patent information. In addition to its theoretical validity and empirical reliability, it commends itself owing to its rather high objectivity. Managers cannot arbitrarily raise their patent output without incurring major expenses and creating potentially commercialisable inventions at the same time (a fundamental prerequisite of international patent law, see Art. 57 European Patent Convention). That said, refining the quantification of patent count data for accounting purposes over a simple multiplication with average values poses an interesting future research question. Depending on the outcome, a future issue will be to discuss whether overall information efficiency is enhanced by including patent data in financial reporting or by disclosing it in some other fashion (Ball, 2001).

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