The valuation of pharmaceutical intangibles

Mark Russell
UQ Business School, The University of Queensland, Brisbane, Australia

Abstract

Purpose – The purpose of this paper is to value the patents of pharmaceutical companies using discounted cash flows, and compare the value-relevance of these assets against alternative intangible asset measures such as reported intangible assets and R&D capital.

Design/methodology/approach – The study values pharmaceutical intangibles using three methods: an income method; the sum of unamortised R&D expenditures; the firm's reported intangible assets. Value-relevance tests use ordinary least squares regression and Vuong and Clarke tests.

Findings – First, the study finds that the discounted cash-flow valuation of pharmaceutical patents is value-relevant. Second, the value of pharmaceutical patents explains market value better than reported intangible assets but not R&D capital. However, the valuation of pharmaceutical patents is more consistent with the risks of R&D than the valuation of R&D capital which assumes recovery of R&D expenditure.

Originality/value – This is the first known study that values patents using an income method and compares those valuations with reported intangible assets and R&D capital valuation models.

Keywords Intangible assets, Valuations

Paper type Research paper

1. Introduction

The study exploits an opportunity to use discounted cash flows to value the drug patents of the world's largest pharmaceutical companies. The study then compares the value-relevance of our patent valuations to other intangible asset measures such as company reported intangible assets and R&D capital.

Although the use of intangible assets is increasing, the valuation of intangible assets is arguably speculative rather than relevant for investment or decision making. According to accounting standards, internal research and development costs are expensed as incurred, and only acquired intangible assets are recognised as assets. This results in the undervaluation of intangible assets. In addition, the heterogeneous nature of intangibles leads to non-standard and noisy measurement methods of their value: resource input measures, output measures, management reported measures and exotic researcher metrics (Wyatt, 2008; Hunter *et al.*, 2012). The failure to recognise intangible assets puts pressure on valuation analysts to use diverse information (Damodaran, 2009). As a result, the use of non-standard valuation information outside the firm reduces the comparability and reliability of the valuations.

The study focuses on intangible assets in the pharmaceutical industry for a number of reasons. The pharmaceutical industry presents an intangible asset-rich sample of companies and high-value blockbuster drugs. Second, pharmaceutical companies have similar product life-cycles, financial structure and operating expenses for the valuation of intangible assets. Importantly, the largest pharmaceutical companies voluntarily disclose drug product sales revenues enabling calculation of future cash flows.

There are three motivations for the research. To the best of our knowledge, this paper is the one of the few to value internally generated intangible assets using an income method. Many R&D studies test the value-relevance of financial and other

Journal of Intellectual Capital
Vol. 17 No. 3, 2016
pp. 484-506

1469-1930
DOI 10.1108/JIC-10-2015-0090

information, or value intangible assets using a large number of different research designs that illustrate the problem of identifying relevant and verifiable information (Wyatt, 2008).

Second, the valuation of intangible assets is of substantial importance to pharmaceutical companies and investors:

> The pharmaceutical industry is in the midst of one of the biggest patent cliffs with Pfizer's multi-billion-dollar blockbuster drug Lipitor losing patent protection in the US in late November 2011 […] other major branded drugs that lost patent protection in the past few months represent branded sales worth more than $15 billion (Zacks Investment Research, Industry Outlook, 2012).

Intangible asset information reduces information asymmetry and also benefits banks and creditors which typically have difficulty in assessing the financial position of companies with intangible assets (Andriessen, 2004).

Third, the study explores whether drug sales, reported intangibles and R&D expenses are useful for valuing pharmaceutical companies. The value-relevance of internally generated pharmaceutical patents provides evidence on the desirability of valuing intangible assets, either for intangible asset standards, or specifically for health care companies as a sector. A primary focus of the Financial Accounting Standards Board and other standard setters is equity investment (Barth *et al.*, 2001).

The key result is that the valuation of pharmaceutical patents by discounted cash flows is value-relevant for companies reporting drug product sales that exceed one-third of total sales revenue. Under those reporting conditions, patent valuation by discounted cash flows dominates valuation by reported intangible assets in explaining the market value of the company.

The study contributes to the debate on reporting intangible assets and identifies conditions when the valuation of intangible assets is useful. The paper provides evidence that the presentation of product sales revenue information assists the valuation of intangible assets and the price discovery of stocks. The study finds that the discounted cash flow method of valuing intangible assets is more useful in assessing the financial position of pharmaceutical companies than company reported intangible assets. The next section reviews the literature and develops the hypotheses. Section 3 outlines the research method, Section 4 reports the valuation of intangible assets and descriptive statistics, Section 5 reports the value-relevance results, and Section 6 concludes the paper.

2. Literature and hypothesis development

The intellectual capital literature has identified and measured many new forms of intangible assets (Andriessen, 2004). These assets include financial and non-financial items (Petty and Guthrie, 2000a). The non-financial items have qualities that are difficult to measure (Catalfo and Wulf, 2016). The intellectual capital literature also indicates several motives for measuring intellectual capital: internal management, external reporting, transactional and statutory (Andriessen, 2004; Lagrost *et al.*, 2010). As a result, there are over 30 methods for measuring and valuing intangible assets (Andriessen, 2004).

This study measures intangible assets with financial data and focuses on one industry. Few recent studies use traditional quantitative methods such as discounted future cash flows to value intangible assets (Lev and Schwartz, 1971; Sadan and Auerbach, 1974). One reason is that tracing a cash flow stream to a specific intangible asset is difficult (Lagrost *et al.*, 2010).

The study addresses the limited financial reporting of intangible assets. The measurement and valuation issues reduce the consensus on what intellectual capital to report. This contributes to limit financial reporting of intellectual capital (Petty and Guthrie, 2000b). More broadly, intellectual capital reporting suffers from low perceived value (Schaper, 2016). Accordingly, there are calls to move intellectual capital information from financial reporting to broader disclosure (Dumay, 2016).

In accounting the recognition and measurement of intangible assets is a controversial topic and presents a challenge to accounting standard setters (Wines and Ferguson, 1993; Alfredson, 2001). One primary issue for standard setters is whether internally generated intangible assets should be recognised like purchased intangible assets (Dahmash *et al.*, 2009).

Intangible assets provide information about future economic benefits. The failure to recognise internally generated intangible assets increases information asymmetry about future company performance. Objections to the capitalisation of intangible expenses centre on the uncertainty associated with the economic benefits of intangibles (Lev and Zarowin, 1999). This uncertainty is partially resolved when property rights attach to investment outputs (Wyatt, 2008; Hunter *et al.*, 2012). In our setting, the patent outputs of pharmaceutical R&D investment contain property rights that help resolve the uncertainty of economic benefits. The drug patents generate cash flows that can be estimated, discounted and valued.

Intangible assets are particularly important to pharmaceutical companies. Chemical and pharmaceutical patents are more valuable than patents in other industries (Bessen, 2008). The discovery and development of new drugs is a very lengthy and costly process (DiMasi *et al.*, 1991). The resulting pharmaceutical patents give the owner the exclusive use of technology to produce products and services (Grabowski, 2002). Pharmaceutical patents are also critical to financial performance in the biotechnology sector. First, the distribution of returns to new drug innovations is highly skewed. Roughly one half of the present value from a sample of 118 compounds between 1990 and 1994 is accounted for by the top-ranked decile of new drug introductions. Median new drug returns do not cover the R&D costs of the average compound (Grabowski *et al.*, 2002).

2.1 The valuation of patents

Intangible assets are generally valued quantitatively by cost, market or income-based methods which include discounted cash flows (Lagrost *et al.*, 2010). Prior technology studies often estimate the value of intangible assets by capitalising R&D expenditures (Lev and Sougiannis, 1999; Chan *et al.*, 2001). However, valuation models using input expenditures on intangibles arguably lack theory for asset valuation (Holthausen and Watts, 2001). A common output of R&D in pharmaceuticals is patents, although simple counts of patents are not useful for valuation (Griliches, 1990). In contrast, asset valuation using cash flows is a model widely accepted in valuation theory and practice (Damodaran, 2009). Further, the forecast of future income from a patent is an improvement on estimating the market value or cost of the patent (Pitkethly, 1997).

A large number of prior studies test the value-relevance of financial and non-financial information in the biotechnology sector (Ely *et al.*, 2003; Xu *et al.*, 2007; Yang, 2007). However, the prior studies on the value of pharmaceutical intangible assets are limited and disparate. The findings of prior studies are also mixed. Shortridge (2004) finds a non-financial measure of R&D success, new drug approvals, is value-relevant. Gleason and Klock (2006) find intangible capital measures based on advertising and R&D explain the variation in Tobin's *Q* ratio. Hartmann and Hassan (2006) find real

analyse real options for R&D projects in the pharmaceutical industry. Mehralian *et al.* (2012) find that intellectual capital, measured by the value added intellectual coefficient, is not associated with the market value of Iranian pharmaceutical companies.

Closer to our study, Boekestein (2006) examines the visibility of reported intangible assets on the balance sheet of pharmaceutical companies. Boekestein (2006) finds an uneven reporting of intangible assets and no correlation between intangible assets and company performance. Finally Boekestein (2006) citing Andriessen (2004) recommends the valuation of intangible assets using future revenues.

The study first uses an income method to value patents. Future cash flows are estimated from drug product sales revenues and expenses. Second, the paper then tests the value-relevance of pharmaceutical patents, reported intangible assets and R&D capital. This is the first known study to value patents by an income method and then test the value-relevance of the patent values. The aggregate value of patents is expected to be value-relevant since the cash flows are substantial. Blockbuster drugs with annual sales in excess of USD 1 billion increased in number from six to 52 between 1997 and 2006 (Aitken *et al.*, 2009; Berndt and Aitken, 2010).

Valuation theory and the multiple valuations of intangible assets lead to the following hypotheses:

H1. The value of pharmaceutical patents is associated with market value.

H2. The value of pharmaceutical patents is associated with market value more than the value of reported intangible assets or R&D Capital.

3. Research method

3.1 Patent valuation

To value pharmaceutical patents the paper first forecasts product sales revenues attributable to company drug patents. Second, free cash flows (FCFs) are calculated by two methods: from pharmaceutical literature estimates of contribution margins; and from pharmaceutical analyst FCF margin estimates.

The study initially uses the following inputs and outputs to estimate FCFs:

- the estimated life of the patent;
- the drug product revenue life cycle;
- forecasted drug product sales revenues;
- contribution margin;
- cost of capital;
- post-approval R&D expense;
- capital investment; and
- tax expense.

In calculating expected cash flows, the study estimates n the remaining useful life of the patents to value the asset:

$$Value\ of\ asset = \sum_{t=1}^{t=n} \frac{Expected\ cash\ flow_t}{(1+r)^t} \quad (1)$$

From the literature, drug product sales revenues peak a number of years after drug approval and then decline at an accelerated rate. Major drug products coming off patent in the 1990s provide four average percentage declines of 31, 28, 20 and 20 per cent, respectively (Grabowski *et al.*, 2002). As a result, the distribution of drug product revenues is expected to be non-linear and finite. The distribution of drug product revenue is illustrated in three stages in Figure 1.

The product life-cycles of drugs have been shortening since the 1980s (Grabowski and Vernon, 1990). From 25 years in the 1970s, the drug life-cycle is estimated to be 20 years (Grabowski *et al.*, 2002). Over the life-cycle, product sales are a function of patents and entry time into the market. Historically, patents commence prior to drug product introduction to the market (Grabowski *et al.*, 2011). Hence post-food and drug administration (FDA) approval, many drugs have patent protection for a period shorter than 20 years. Patents have a limited life and their valuation does not include a terminal value.

3.2 Forecast of drug product sales revenue

To forecast drug product sales revenue the study first models historical sales revenue from industry data. The distribution of sales revenue is derived from the data and selected according to fit statistics. The literature indicates that drug product sales are continuous, asymmetric and have positive outliers which suggest a non-normal distribution.

Using a selected continuous probability distribution, the study models historical sales revenue as a function of post-FDA approval year or pre-patent expiry year, company indicator variables, and a multiple lag of sales revenue. The drug life-cycle indicates that drug product sales increase then decrease. Accordingly, the study expects a logarithmic or exponential distribution and the following model to best fit the available data:

$$Sales\ revenue_t = \alpha_0 + \sum_{t-n}^{t-1} (\alpha_t Sales\ revenue) + \alpha_t Year + \sum \alpha_t Company + \varepsilon \quad (2)$$

where *Sales Revenue* is annual drug sales revenue of product j at time t, *Year* is post-approval for sale year or pre-patent expiry year, *Company* is an indicator variable.

The models of sales revenue are tested iteratively for significant variable coefficients. The results determine the number of lags of sales used in the model. Further, for drug products with short data series the study uses supplementary estimation of sales revenue using one-year and two-year lags of sales revenue at each post-approval year and pre-expiry year. The models are augmented with an autoregressive model of the random error term to correct for serial correlation:

$$Sales\ revenue_t = \alpha_0 + \sum_{t-2}^{t-1} (\alpha_t Sales\ revenue) + \varepsilon + \sum_{t-2}^{t-1} (\theta_t \beta) \quad (3)$$

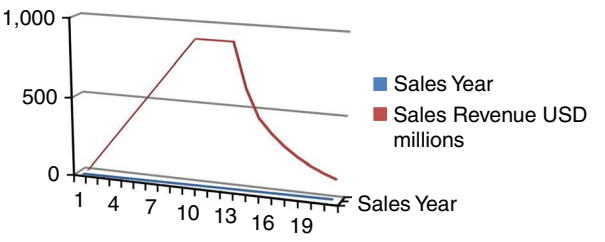


Figure 1.
Expected stages of drug product sales revenues

The model (2) and (3) coefficients α of lagged sales, year and company are then used to forecast sales revenues for individual drugs at each post-approval year or pre-expiry year over the life of the patent. In total, the forecast sales are based on a 15 year post-drug approval period or up to US patent expiry year, depending on data availability for each drug. The 15 year post-drug approval period aligns with a plot of the sales data and the expected duration of patent protection. An inspection of the US FDA Orange Book data files and the US Patent and Trademark Office (USPTO) records indicate that most drugs have multiple dosage and delivery method patents which extend patent protection periods. The outcome is that many drugs enjoy extended patent protection towards their estimated 20 year life-cycle.

A discount rate reflecting the cost of capital is used to discount the expected cash flows. Between 1994 and 2000 the real cost of capital for the pharmaceutical industry, using the CAPM model, varies from 10.6 to 12.0 per cent, with a mean just over 11 per cent (DiMasi *et al.*, 2003). The study first uses a discount rate of 11 per cent and in sensitivity testing uses a rate of 7 per cent based on pharmaceutical stock analyst estimates.

3.3 Contribution margin and FCFs

The expenses attributable to individual drug products are not generally reported in financial statements. Therefore the study derives FCFs by estimating outgoings associated with sales revenues. The outgoings are initially guided by the literature before using analyst estimates of FCF margins.

A drug's contribution margin, the unit revenue minus unit production and distribution costs, is first used to estimate FCFs. That is, sales are multiplied by a contribution margin to estimate the FCF. Pharmaceutical contribution margins between 1973 and 1987 varied between 33 and 40 per cent (Grabowski and Vernon, 1990). More recent estimates of the mean contribution margins are 45 per cent over the 20 year life cycle of the drug (Grabowski *et al.*, 2002) and the study initially adopts the 45 per cent margin. In addition to the variable costs of production and distribution, pharmaceutical products incur additional expenses in R&D, marketing and capital investment as follows:

R&D – A survey of ten multinational pharmaceutical companies show that companies spent approximately 15% of R&D expenditures on improvements to drugs that have already been approved (DiMasi *et al.*, 2003). R&D expenditures are apportioned to forecasted drug sales based on the ratio of reported company R&D expense to total sales revenue of the company.

Marketing – Rosenthal *et al.* (2002) and Healy *et al.* (2002) indicate that the drug industry's marketing expenses to sales ratios vary over the drug life-cycle finishing at 6.5%.

Capital Investment – Grabowski *et al.* (2002) calculate an average capital investment to sales ratio of 3.3% over the full product life cycle.

Tax Rate – The average effective U.S. tax rate of a sample of 66 new chemical entities (NCEs) in the 1990s is 30% (Grabowski *et al.*, 2002).

3.4 The valuation of R&D capital

The study estimates a second measure of intangible assets, R&D capital. R&D capital, is estimated from current and past R&D expenditure (Lev and Sougiannis, 1999; Chan *et al.*, 2001):

$$R\&D\ \ capital_{it} = \sum \alpha_k R\&D\ expense_{t-k} \tag{4}$$

The coefficients α_k are the unamortised portion of annual R&D expenditures and are estimated by two methods. The first method estimates the amortisation rate using a yearly cross-sectional regression of company *i*:

$$OI = \alpha + \alpha TA + \sum \alpha_k R\&D\ expense + \alpha Ad\ expense + \varepsilon \quad (5)$$

where *OI* is annual operating income before depreciation, advertising and R&D expenses at year $t-1$; *TA* is tangible assets, the value of property plant, and equipment, inventory, goodwill and investment in associated companies at year $t-1$; *R&D expense* is annual R&D expenditure at year $t-k$; *Ad expense* is annual advertising expenses at year $t-1$; and all variables are scaled by annual sales to mitigate heteroscedasticity.

The amortisation rate for each year δ_k is the ratio of $\alpha_k/\sum\alpha_k$ which is the ratio of benefits expired in year *t* to total benefits of the R&D expenditure (Lev and Sougiannis, 1999). Pooled and annual samples are tested to estimate amortisation rates. Calculating the amortisation rate δ_k results in the following estimation of R&D capital:

$$R\&D\ capital_{it} = \sum R\&D\ expense_{t-k}\left[1-\sum_{j}^{k}\delta_j\right] \quad (6)$$

The advertising expense variable in model (5) is not available in the compustat global annual database so the model is estimated both with and without advertising expenses.

The second method of estimating the amortisation rate assumes a linear 20 per cent capital amortisation rate and five R&D lags (Chan *et al.*, 2001):

$$R\&D\ capital_{it} = R\&D\ expense_{it} + 0.8 \times R\&D\ expense_{it-1} + 0.6 \times R\&D\ expense_{it-2} + 0.4 \times R\&D\ expense_{it-3} + 0.2 \times R\&D\ expense_{it-4} \quad (7)$$

3.5 The value-relevance of pharmaceutical intangibles

Following the valuation of intangible assets the study compares their value-relevance and the value-relevance of reported intangible assets. To test value-relevance, the study uses a modified Barth and Clinch (1998) model of firm value using the valuations of intangible assets (*INTANGIBLE)* for company *i* with the added controls for book value and income:

$$Value_{it} = \alpha + \beta BVE_{it} + \gamma Net\ income_{it} + \delta_{it}\sum_{1}^{n} INTANGIBLE_{it} + \in_{it} \quad (8)$$

where *value* is the market value of company *i* three months after the fiscal year end *t*, measured by the product of stock price and the number of outstanding shares, Book value of equity (*BVE*) is measured as the reported value of net assets less total intangible assets at fiscal year end *t* for company *i*, *net income* is reported (GAAP) net income before extraordinary items at fiscal year end *t* for company *i*, *INTANGIBLE* is measured alternatively as reported intangible assets; the value of R&D Capital; or the sum of estimated patent values at fiscal year end *t* for company *i*.

Two econometric issues in level-based regression studies are the scale differences among sample firms and heteroscedasticity that result in biased and inefficient coefficient estimates (Christie, 1987; Barth and Kallapur, 1996). Accordingly, to control for this scale effect and heteroscedasticity, the study deflates the regression variables

in model (8) by the number of outstanding shares and by the market value of equity (Easton and Sommers, 2003; Barth and Clinch, 2009).

4. Empirical analysis and descriptive statistics

4.1 Sample and data

The initial sample comprises the 60 largest stock-exchange listed pharmaceutical companies ranked by market capitalisation in US dollars between 2002 and 2012 with at least two years price and financial report data. Stock prices, currency rates and financial report data are obtained from Compustat USA and Compustat Global databases. The sample is further determined by individual drug product sales revenues hand-collected from company financial reports. Drug and patent data are hand-collected from the US FDA Orange Book data files and the USPTO records.

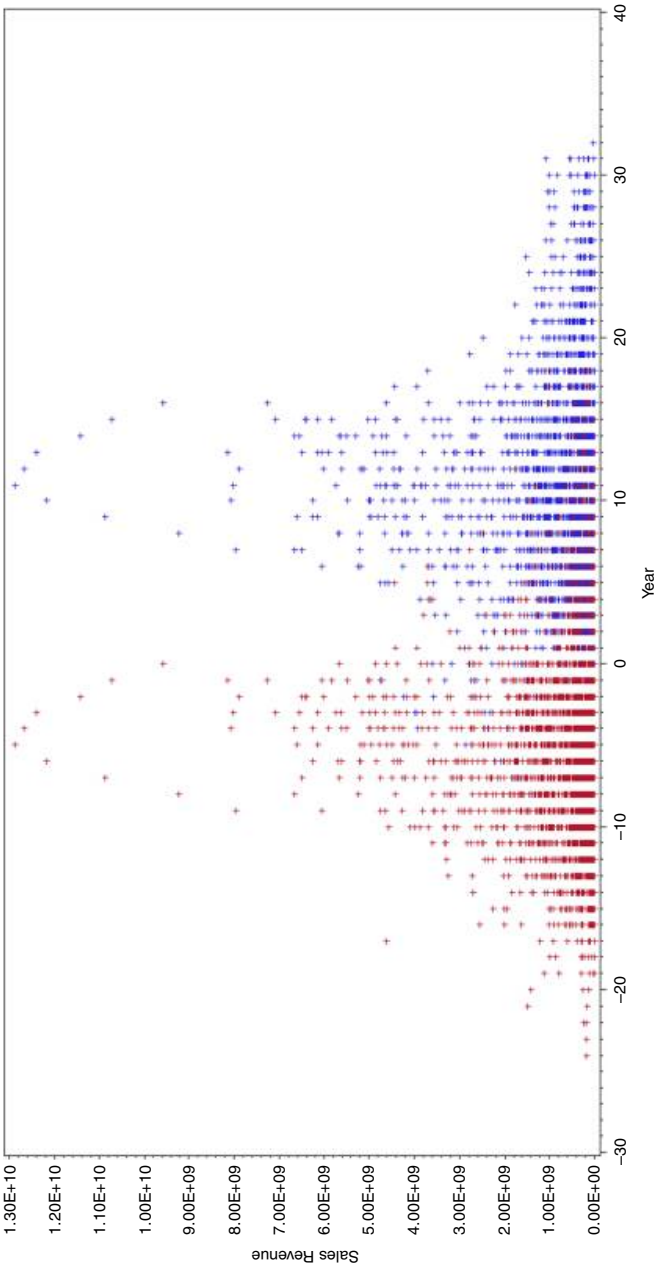
Patent expiry dates are not available for some drugs so patent protection is also estimated from the date of FDA approval for sale. Further, the FDA and USPTO data reveal that proprietary drug products reported in financial statements often have multiple patents based on different dosage routes, forms and strengths of active ingredient. As a result drug products have numerous approval for sale and patent expiry dates influencing patent life. The study adopts the earliest US FDA approval for sale and patent expiry dates associated with the active ingredient and proprietary drug name to calculate pre-patent expiry revenue. Patent expiry dates are further extended for exclusivity expiration dates as reported by the US FDA. The resulting drug data sample of 5,403 observations is reduced to 3,715 observations with available approval dates or patent-expiry dates.

4.2 Historical and forecast drug product sales

Figure 2 plots product sales revenue against post-approval year and pre-expiry year, respectively. In Figure 2, the blue observations illustrate the existence of drug sales revenue before US FDA approval for sale indicating foreign sales. Further, the red observations illustrate large sales revenues after patent expiry year, indicating multiple patents by dosage and foreign patents. Overall, the plots of sales revenues by both post-approval year and pre-expiry year are consistent with patent protection for a 15-year period post-FDA approval.

The drug product sales sample is best modelled by a burr distribution according to likelihood-based statistics of fit. Using the burr distribution the study iteratively models sales revenue with multiple lags of sales revenue, year and company indicator variables. Table I presents the maximum likelihood estimates of a six-lag sales model with statistically significant coefficients. Notably, the lagged sales coefficients switch from positive to negative between lags three and six consistent with a non-linear distribution. The positive theta scale value indicates sales revenue is dispersed which is consistent with the existence of blockbuster drug sales. The company indicator coefficients are largely insignificant which is consistent with sales largely determined by a product life cycle.

The coefficient estimates in Table I are then used to forecast sales in model (2) up to patent expiry or 15 years post-FDA drug approval. The forecasted product sales revenues are illustrated in Figure 3. The forecasted distribution is consistent with the historical distribution of product sales revenues, a 20 year drug life-cycle, with a delayed decline in sales post-patent expiry.



Notes: n=3,715 observations. Drug product sales revenue is reported annual USD drug product revenue at financial year end. Year 0 is US FDA drug approval for sale year (blue observations) and expiry year of earliest US FDA drug patent (red observations). Totally, 2,774 observations are common to both blue and red samples

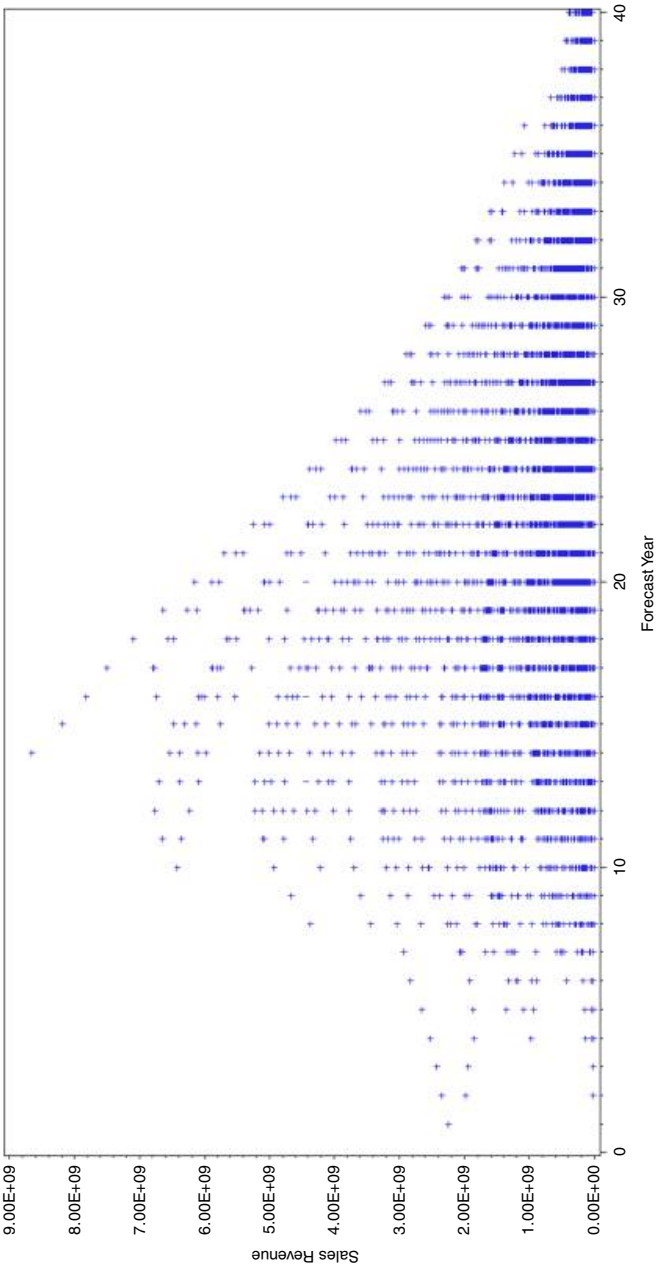
Figure 2.
Plot of drug product sales revenue (USD) vs US FDA post-approval year (blue observations); plot of drug product sales revenue (USD) vs patent pre-expiry year (red observations)

$$exp(Sales\ revenue_t) = \theta_{0*} exp\left[\sum_{t-6}^{t-1}(\alpha_t Sales\ revenue) + \alpha_t Year + \sum \alpha_t Company\right] \times \varepsilon \quad (9)$$

Sales revenue$_t$	Estimate	*t*-value	Approx Pr > |*t*|	Estimate	*t*-value	Approx Pr > |*t*|
θ	2.426	3.990	< 0.0001	2.317	3.870	0.0001
Sales revenue$_{t-1}$	0.680	24.480	< 0.0001	0.745	24.410	< 0.0001
Sales revenue$_{t-2}$	0.255	9.000	< 0.0001	0.244	7.690	< 0.0001
Sales revenue$_{t-3}$	0.126	4.140	< 0.0001	0.110	3.550	0.0004
Sales revenue$_{t-4}$	0.006	0.180	0.8557	−0.042	−1.210	0.226
Sales revenue$_{t-5}$	−0.026	−0.810	0.4208	−0.025	−0.780	0.4381
Sales revenue$_{t-6}$	−0.077	−3.720	0.0002	−0.074	−4.050	< 0.0001
Post-approval year	−0.007	−4.140	< 0.0001			
Pre-expiry year				−0.008	−4.150	< 0.0001
Bristol-Myers Squibb	0.138	1.020	0.3101	0.139	0.910	0.3645
Forest Laboratories, Inc.	0.000	0.000	0.000	0.000	0.000	0.000
GlaxoSmithKline PLC	0.379	2.820	0.0049	0.356	2.310	0.021
Johnson & Johnson	0.057	0.400	0.6886	0.091	0.570	0.5671
Eli Lilly and Company	0.148	1.100	0.2703	0.128	0.830	0.4049
Merck & Co., Inc.	0.097	0.710	0.4789	0.125	0.810	0.4189
Novo Nordisk	0.098	0.600	0.5512	0.169	1.040	0.301
Pfizer Inc.	0.077	0.580	0.5608	0.081	0.540	0.592
Teva Pharmaceutical Industries Limited	0.173	1.210	0.2262	0.174	1.090	0.2747
Allergan Inc.	0.138	0.970	0.3347	0.124	0.780	0.4377
Roche Group	0.150	1.130	0.258	0.114	0.760	0.4486
AstraZeneca	0.114	0.860	0.3885	0.104	0.690	0.4915
Mitsubishi Tanabe Pharma	0.000	0.000	0.000	0.000	0.000	0.000
Bayer AG	0.104	0.760	0.4487	0.083	0.540	0.59
Ono Pharmaceutical Co., Ltd	0.000	0.000	0.000	0.000	0.000	0.000
Daiichi Sankyo Co., Ltd	0.022	0.150	0.8817	−0.013	−0.080	0.9364
Eisai	0.014	0.070	0.9411	0.005	0.030	0.9763
Chugai Pharmaceutical Co. Ltd	0.073	0.520	0.6053	0.002	0.010	0.9921
Kyowa Hakko Kirin Co., Ltd	0.152	1.050	0.295	0.204	1.150	0.2508
Taisho Pharmaceutical Holdings	0.072	0.410	0.6797	0.110	0.580	0.5619
Astellas	0.095	0.660	0.5073	0.002	0.010	0.9883
Shionogi	−0.189	−1.170	0.2414	−0.044	−0.280	0.7781
Takeda Pharmaceutical Company Ltd	−0.144	−0.910	0.3609	0.076	0.380	0.7035
UCB	0.037	0.260	0.7937	−0.001	−0.010	0.9952
Sanofi	0.014	0.110	0.9148	0.032	0.210	0.8336
Novartis	0.169	1.270	0.2048	0.115	0.760	0.4455
Warner Chilcott	0.039	0.220	0.823	0.066	0.350	0.7297
Shire PLC	0.025	0.170	0.8615	−0.015	−0.090	0.9267
Dr Reddy's Laboratories Ltd	0.000	0.000	0.000	0.000	0.000	0.000
Lundbeck	−0.064	−0.410	0.6854	−0.001	0.000	0.9961
Otsuka Holdings Co., Ltd	0.000	0.000	0.000	0.000	0.000	0.000
−2 Log likelihood'	33,540			33,705		
AICC	33,616			33,780		
Observations	823			826		

Notes: *Sales revenue* is the natural logarithm of reported annual USD drug product revenue at financial year end *t*. *Year* is the *post-approval year*, US FDA drug approval for sale year, or *pre-expiry year*, the earliest year of US FDA drug patent expiry for drug proprietary name; company variables are indicator variables; *exp* is the natural exponential function; θ is the distribution scale parameter; the coefficient is reported above the *t*-value

Table I. Maximum likelihood estimation of drug product sales revenues from lags of revenue, year and company for the period 2002-2013



Notes: $n = 9{,}537$ observations. Sales revenue is forecast annual USD drug product revenue at financial year end for forecast years 1 to 40 inclusive; forecast year is year of estimated sales

Figure 3.
Plot of forecast drug product sales revenue (USD) vs forecast year

The forecast sales are then used to estimate FCFs and value drug patents. Figure 4 illustrates the size and distribution of drug patent valuations grouped into a sample of 31 pharmaceutical companies with available data. The distribution confirms the existence of outlier blockbuster drugs.

4.3 R&D capital amortisation and valuation

The lengthy lead period between R&D expenditure and economic benefits in the pharmaceutical industry raises the possibility that model (5), with operating income (OI) as the dependent variable, may not accurately estimate amortisation rates for R&D. In addition, many smaller companies report an annual operating loss before and after depreciation, advertising and R&D expenses. The loss companies create a negative association between R&D and OI over the full sample of pharmaceutical companies.

Nevertheless, in the R&D amortisation model (5) significant coefficients result from testing a subsample of large pharmaceutical companies using a simple one period lag R&D model. Adding advertising expense to model (5) reduces the sample size to US reporting companies and results in insignificant coefficients on R&D or lag R&D variables. Hence advertising expense is omitted from model (5).

Table II presents ordinary least squares estimates of the R&D amortisation model (5) which examines the contributions of tangible and intangible assets to OI. The R&D and the lag of R&D coefficients are both significant. The negative coefficient on tangible assets which is significant at the 5 per cent level indicates that pharmaceutical firms with a higher proportion of tangible assets perform less profitably. Firms in the sample operate beyond pharmaceuticals in biotechnology, diagnostics and medical device segments.

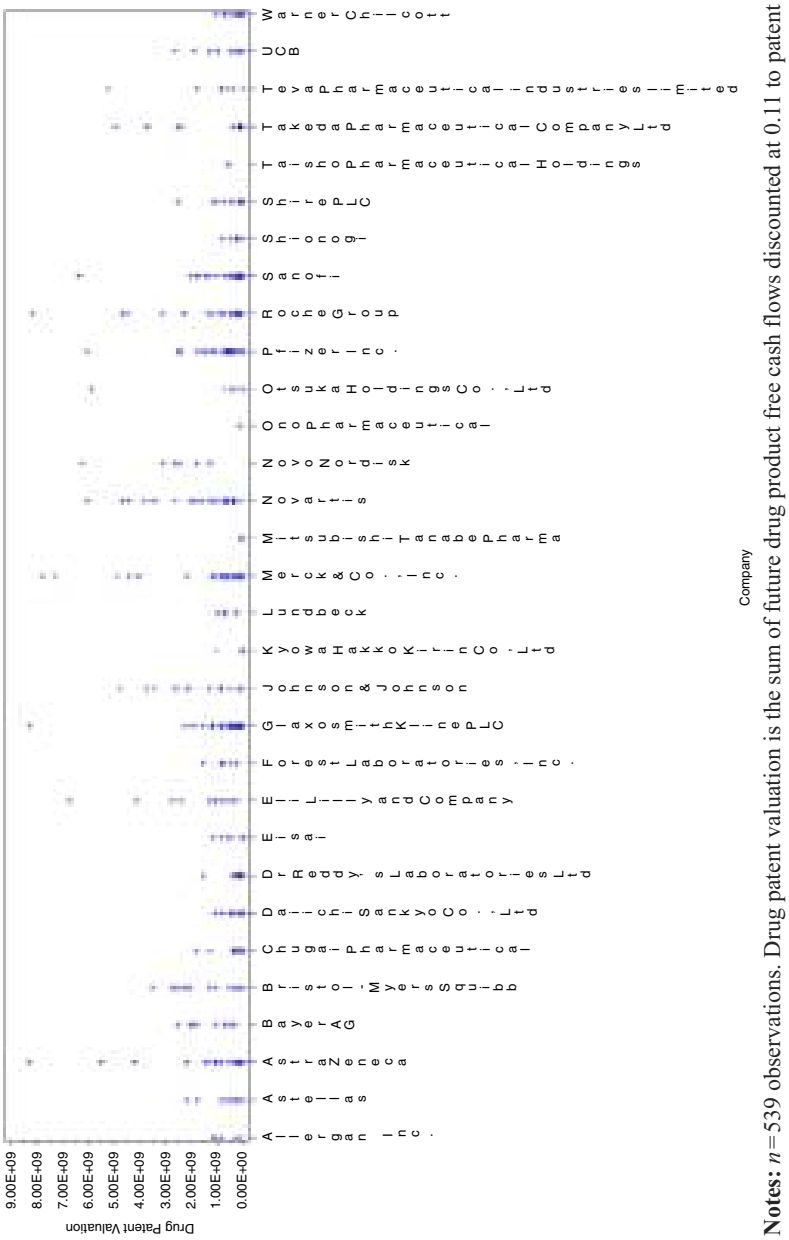
Figure 5 presents the distribution of annual R&D capital (CLS) valuations of 31 pharmaceutical companies. The distribution illustrates the comparative amount spent on R&D between companies. From the lagged structure of the R&D capital formula, the valuations per company are bunched with a wider spread indicating a change in R&D expenditure over time.

4.4 Descriptive statistics

Table III presents descriptive statistics using the sample of 60 pharmaceutical companies and a sample of 539 drug products. The higher mean than median of product sales revenue is consistent with a number of outlier observations. The mean drug patent valuations include drugs close to patent expiry and are marginally higher than sales revenues.

Table III also presents descriptive statistics for annual R&D capital valuations using the sample of 31 pharmaceutical companies. As expected from the R&D amortisation model (5) results, the Lev and Sougiannis (1999) (LS) method valuations are substantially lower than those of Chan *et al.* (2001) (CLS). The R&D capital (CLS) valuations are lower but a similar scale to the company patent valuations despite the contrasting input and output methods of valuation. In contrast, the minimum R&D capital (CLS) valuation is double the minimum company patent valuation.

Further, Table III presents descriptive statistics for variables in the value-relevance model (8). The company patent valuations have a higher median but lower mean than total intangible assets which is consistent with total intangible assets containing acquired R&D and other intangibles such as goodwill. Finally, Table III presents descriptive statistics for three sales and valuation ratios: the ratio of drug product sales



Notes: $n = 539$ observations. Drug patent valuation is the sum of future drug product free cash flows discounted at 0.11 to patent expiry or to 15 years post-approval

Figure 4.
Plot of drug patent valuation (USD) by company

$$OI = \alpha + \alpha TA + \sum \alpha_k R\&D\ expense_t + \varepsilon \quad (10)$$

Dependent variable	Operating income
Intercept	0.299 (16.18)***
Tangible assets (*t*–1)	−0.033 (−2.41)**
R&D (*t*)	0.952 (13.99)***
R&D (*t*–1)	0.185 (2.89)***
Adjusted R^2	0.455
F-statistic	104.13
Observations	371

Notes: *OI* is annual operating income before depreciation, advertising and R&D expenses at year *t*; *TA* is tangible assets, the value of property plant, and equipment, inventory, goodwill and investment in associated companies at year *t*−1; *R&D* is annual *R&D* expenditure at year *t*. All variables are scaled by annual net sales at year *t*; the coefficient is reported above the *t*-statistic. **,***Significant at 5 and 1 per cent level, respectively

Table II.
Cross-sectional regression of operating income on R&D expenses and tangible assets for the financial years 2000 to 2013

to company sales, and the ratios of company patent valuation to total assets and to reported intangible assets, respectively. The statistics indicate that a number of pharmaceutical companies disclose low patented drug revenues and few intangible assets. Most of the low-disclosure companies in the sample are Japanese which is consistent with and earlier finding of Boekestein (2006).

Table IV presents correlations for variables in value-relevance model (8).

The variable correlations are generally strong. BVE has a relatively weaker correlation with patent valuation which suggests that intangible outputs are less predictable from the firm's reported assets.

5. Results

The study first tests value-relevance model (8) using ordinary least squares (OLS) regression with undeflated variables. Of the intangible asset measures, only reported intangible assets is significantly associated with market value. Plots of the data and white tests indicate the existence of heteroscedascity. Accordingly, model (8) is tested with deflated variables. The results of testing model (8) with variables deflated by shares outstanding are significant. The coefficients of patent valuation and reported intangible assets are significant at the 0.05 level, and significant at the 0.01 level for both measures of R&D capital. In contrast, the results of testing model (8) with variables deflated by market value of equity are insignificant. The mixed results lead to additional tests.

5.1 Additional tests

The descriptive statistics indicate a number of low-disclosure companies with low patented drug sales and few intangible assets. The financial reports of these companies confirm active pipelines of R&D and exclude the companies as generic drug manufacturers. Additional OLS regression tests are conducted on a subsample of companies with disclosed product sales to total sales ratios above one-third. The study expects patents to be more important for companies whose patented drug sales are a higher proportion of total sales.

Table V presents the results of testing the value-relevance of intangible asset measures with variables deflated by market value of equity.

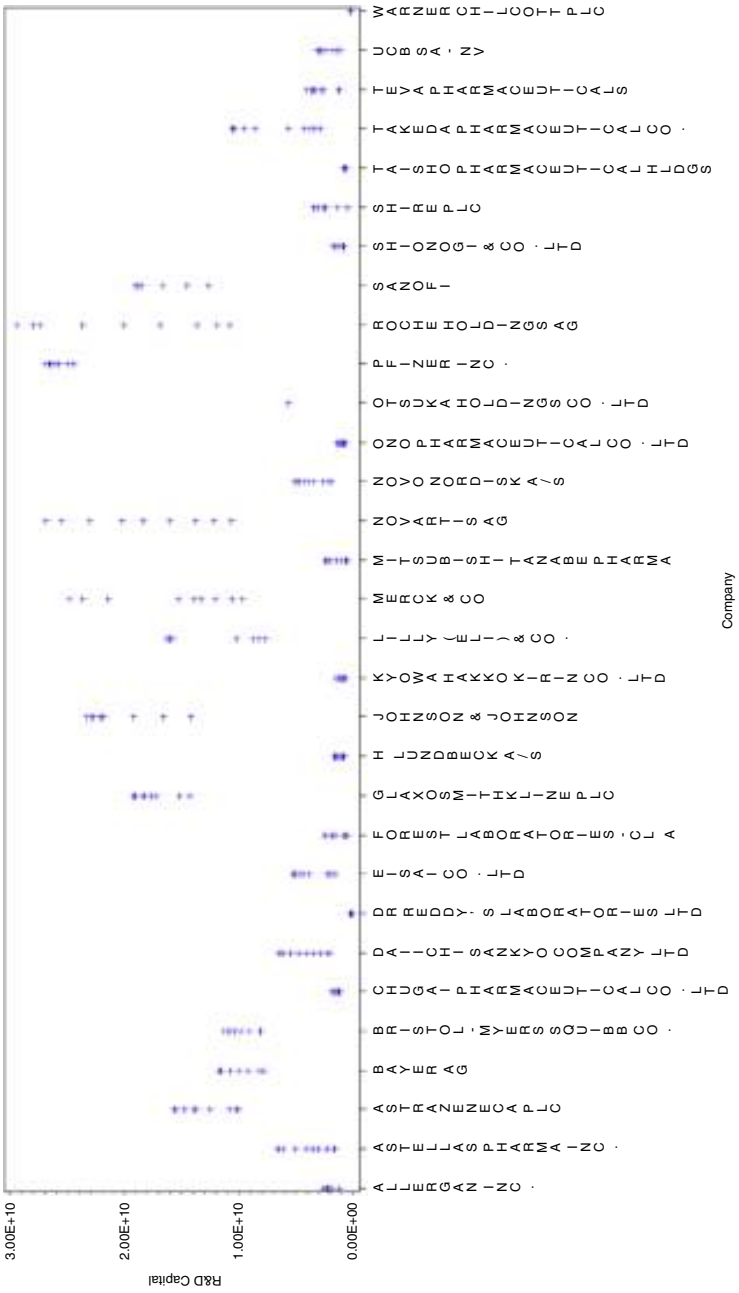


Figure 5.
Plot of R&D capital (Chan Lakonishok Sougiannis) (USD) by company

Notes: $n = 278$ observations. $R\&D\ capital_{it} = R\&D\ expense_{it} + 0.8 \times R\&D\ expense_{it-1} + 0.6 \times R\&D\ expense_{it-2} + 0.4 \times R\&D\ expense_{it-3} + 0.2 \times R\&D\ expense_{it-4}$ (11)

	Mean	SD	Median	Maximum	Minimum	Skewness	Kurtosis	Obs.
Sales revenue	7.66E+08	1.17E+09	3.64E+08	1.29E+10	0	3.942	23.270	3,715
Forecast sales revenue	8.52E+08	1.03E+09	4.86E+08	8.66E+09	7.80E+04	2.742	9.351	9,537
Drug patent valuation	9.89E+08	1.38E+09	4.79E+08	8.33E+09	1.79E+04	2.739	8.657	539
Company patent valuation	1.503E+10	1.468E+10	8.953E+09	5.111E+10	1.491E+08	1.096	0.334	31
R&D capital (CLS)	9.322E+09	9.231E+09	5.152E+09	2.943E+10	3.071E+08	0.935	−0.537	31
R&D capital (LS)	5.178E+08	5.113E+08	3.128E+08	1.694E+09	1.672E+07	0.984	−0.347	31
Value	6.045E+10	6.881E+10	1.789E+10	2.280E+11	3.395E+09	1.150	0.112	31
Price	5.430E+01	4.705E+01	4.119E+01	2.335E+02	1.133E+01	2.184	6.120	31
BVE	1.973E+10	2.346E+10	1.010E+10	8.168E+10	−6.000E+08	1.703	1.677	31
Net income	2.981E+09	3.489E+09	1.099E+09	1.085E+10	1.259E+08	1.168	−0.038	31
Intangibles	1.657E+10	2.396E+10	3.516E+09	9.069E+10	1.205E+07	1.857	2.866	31
Drug/total sales	0.500	0.262	0.518	0.931	0.039	−0.127	−1.109	31
Patent/total assets	0.628	0.524	0.509	2.356	0.018	1.665	3.171	31
Patent/intangibles	15.911	59.218	1.751	325.928	0.132	5.139	27.313	31

Notes: *Sales revenue* is reported annual drug product revenue at financial year end *t*; *forecast sales revenue* is forecasted annual drug product revenue at financial year end; *drug patent valuation* is the sum of future drug product cash flows discounted at 0.11 to patent expiry or to 15 years post-approval. *Company patent valuation* is the pharmaceutical company's aggregate drug patent valuations; *R&D capital CLS* is Chan *et al.* (2001) estimation of company *R&D capital* being $R\&D\ capital_{it} = R\&D\ expense_{it} + 0.8 \times R\&D\ expense_{it-1} + 0.6 \times R\&D\ expense_{it-2} + 0.4 \times R\&D\ expense_{it-3} + 0.2 \times R\&D\ expense_{it-4}$; *R&D capital LS* is Lev and Sougiannis (1999) estimation of company *R&D capital* being the unamortised portion of α in a regression of $OI = \alpha + \alpha TA + \sum \alpha_k R\&D\ expense_t + \varepsilon$; *value* is absolute close market price of common stock three months after financial year end multiplied by common stock outstanding; *price* is absolute close market price of common stock three months after financial year end; *BVE* is fiscal year end common equity; *net income* is income before extraordinary items at financial year end *t*; *intangibles* is reported total intangible assets at financial year end *t*; *drug/total sales* is drug product sales revenue divided by sales revenue at financial year end *t*; *patent/total assets* is company patent valuation divided by total assets at financial year end *t*; *patent/intangibles* is company patent valuation divided by intangibles at financial year end *t*

Table III. Descriptive statistics for drug product, patent, pharmaceutical companies (USD) for the period 2002-2013

The results support hypothesis one. Company patent valuations and other intangible asset measures are value-relevant at the 0.05 level of significance. Unreported test results with the variables deflated by number of shares outstanding are broadly consistent with the above results, with R&D capital coefficients significant at the 0.01 level and the reported intangible asset coefficient is insignificant.

5.2 FCF margin sensitivity tests

The estimation of FCF margins from sales revenue changes over time and varies by company. In 2015 sell-side analyst reports of companies in our final sample indicate that the cost of capital is closer to 7 per cent than the earlier 10 per cent, and the long run tax rate is 21-22 per cent. The analyst reports also provide a five year projected average FCF margin between 21.8 and 24.4 per cent and a three year historical average FCF margin between 15.5 and 17.8. Accordingly, the study recalculates FCFs based on FCF margins between 14 and 24 per cent with a cost of capital of 7 per cent. Tests of value-relevance in model (8) with variables deflated by number of shares outstanding and by market value of equity are consistent with earlier results for all FCF margins.

		A.	B.	C.	D.	E.	F.	G.
Pearson correlations								
A.	*Value*	1	0.846	0.934	0.799	0.842	0.879	0.888
B.	*BVE*	0.852	1	0.780	0.722	0.966	0.792	0.782
C.	*Net Income*	0.924	0.785	1	0.856	0.772	0.946	0.954
D.	*Company patent valuation*	0.854	0.742	0.871	1	0.702	0.921	0.911
E.	*Total intangible assets*	0.786	0.781	0.750	0.777	1	0.766	0.747
F.	*R&D capital (CLS)*	0.903	0.861	0.873	0.873	0.801	1	0.996
G.	*R&D capital (LS)*	0.912	0.869	0.877	0.875	0.794	0.994	1

Spearman correlations

Value is absolute close market price of common stock three months after financial year end multiplied by common stock outstanding; *BVE* is fiscal year end common equity; *net income* is income before extraordinary items; *company patent valuation* is the company aggregate of future drug cash flows discounted at 0.11 to patent expiry or to 15 years post-approval; *INTANGIBLES* is reported total intangible assets at financial year end t; *R&D capital (CLS)* is Chan *et al.* (2001) estimation of company R&D Capital; *R&D capital (LS)* is Lev and Sougiannis (1999) estimation of company R&D capital

Notes: $n = 31$ observations. Annual pooled sample for financial years ended 2012 and 2013

Table IV.
Correlation matrix of value-relevance model (8) variables

$$Value_{it}/Value_{it} = \alpha_1/Value_{it} + \beta BVE_{it}/Value_{it} + \gamma Net\ income_{it}/Value_{it} + \sum_{1}^{2} \delta INTANGIBLE_{it}/Value_{it} + \in_{it} \quad (12)$$

Intercept	−3.222E+09 (−1.83)	−4.211E+08 (−0.44)	−5.903E+08 (−0.58)	−5.891E+08 (−0.6)
BVE	0.495 (2.180)**	0.757(2.980)***	0.065 (0.230)	−0.001 (0.000)
Net income	9.202 (3.170)***	10.459 (4.580)***	10.616 (4.370)***	9.860 (4.030)***
Company patent valuation	1.216 (2.260)**			
Total Intangible Assets		1.017 (2.560)**		
R&D capital (CLS)			1.637 (2.250)**	
R&D capital (LS)				34.738 (2.570)**
Adjusted R^2	0.886	0.893	0.886	0.893
F-statistic	41.8	44.8	41.7	44.9
Observations	21	21	21	21

Notes: *Value* is absolute close market price of common stock at financial year end multiplied by common stock outstanding; *BVE* is fiscal year end common equity minus total reported intangible assets; *net income* is income before extraordinary items; *patent* is the company aggregate of future drug cash flows discounted at 0.11 to patent expiry or to 15 years post-approval; *intangibles* is reported total intangible assets at financial year end *t*; *R&D capital* (*LS*) is Lev and Sougiannis (1999) estimation of company R&D capital; *R&D capital (CLS)* is Chan *et al.* (2001) estimation of company R&D Capital. Annual pooled sample for financial years ended 2012 and 2013. Coefficient reported above *t*-statistic; *,**,***Significant at 10, 5, and 1 per cent levels, respectively

Table V.
Cross-sectional regression of intangible asset value-relevance

5.3 Vuong and Clarke tests

The study further tests intangible asset measures in alternate models to explain market value. The paper uses the Vuong (1989) and Clarke (2001) likelihood-ratio based tests with the null hypothesis that both models are equally distant from the true model against the two-sided alternative that one model is closer to the true model. Vuong and Clarke tests of

model (8) use undeflated variables and variables deflated by stock price. For the model (8) variables deflated by market value of equity, the predictor variables are on vastly different scales which causes covariance estimation issues and unreliable parameter estimates.

Table VI presents results of the Vuong and Clarke tests which provide evidence that the company patent valuations are preferred to reported intangible assets but not R&D capital as a predictor of company value.

Unreported Vuong and Clarke tests of model (8) with undeflated variables indicate that company patent valuations are preferred to R&D capital but not reported intangible assets as a predictor of company value. Overall, the results are highly sensitive to variable scaling and partially support hypothesis two. In further sensitivity testing, the company patent valuations are recalculated using analyst FCF margins from 14 to 24 per cent. The Vuong and Clarke test results with new company patent valuations are consistent with earlier results.

Overall, the study goes beyond previous studies by valuing pharmaceutical intangible assets using the discounted cash flow method, and then testing the value-relevance of intangible asset valuations. Generally pharmaceutical studies either test the value-relevance of financial and non-financial information, or are descriptive in nature. In particular, Hartmann and Hassan (2006) examine the use of valuation techniques and Boekestein (2006) examines the reporting of intellectual capital, and the correlation between intangible assets and company performance.

6. Conclusion

The study values intangible assets from a time-series of cash flow outputs traceable to identifiable and separable intangible assets. As predicted pharmaceutical sales revenues have a non-linear distribution with a drug life-cycle approaching 20 years.

In summary, the study finds that pharmaceutical patents are value-relevant where, reported drug product sales exceed one third of total revenues, and second, patent valuation models are preferred to reported intangible assets in explaining the market value of large pharmaceutical companies.

In more detail there are two main findings. First, the valuation of patents for large pharmaceutical companies is value-relevant at the 0.05 level of significance for companies with reported drug product sales that exceed one-third of total revenues. In addition, the study finds the same associations between company value, reported intangible assets and R&D capital.

Further the minimum value of company patents is one-half of the minimum value of the R&D capital (CLS) estimation. The results suggest that patent valuation from cash flows better incorporates the risks of R&D investment as the R&D capital valuation models assume economic recovery of R&D expenditure whereas patent valuation makes no such assumption. The results are consistent with the risky nature of R&D activity and the skewed distribution of returns to R&D activity in the pharmaceutical industry (Grabowski *et al.*, 2002).

Second, patent valuation models are preferred to reported intangible assets but not R&D capital in explaining the market value of large pharmaceutical companies. The results of Vuong and Clarke tests are mixed and sensitive to variable scaling in the value-relevance model (8). Overall, hypothesis two is partially supported.

The study also contributes to the valuation of intangible assets and the economics of disclosure. The paper illustrates disclosure conditions when intangible asset valuation is useful to investors. For pharmaceutical companies, the usefulness of intangible asset information is potentially high because of information asymmetry and the lengthy drug

$$Price_{it} = \alpha + \beta BVE\_ps_{it} + \gamma Net\ income\_ps_{it} + Company\ patent\ valuation\_ps_{it} + \in_{it} \quad (12.1)$$

$$Price_{it} = \alpha + \beta BVE\_ps_{it} + \gamma Net\ income\_ps_{it} + Total\ intangible\ assets\_ps_{it} + \in_{it} \quad (12.2)$$

$$Price_{it} = \alpha + \beta BVE\_ps_{it} + \gamma Net\ income\_ps_{it} + R\&D\ capital\ (CLS)\_ps_{it} + \in_{it} \quad (12.3)$$

$$Price_{it} = \alpha + \beta BVE\_ps_{it} + \gamma Net\ income\_ps_{it} + R\&D\ capital\ (LS)\_ps_{it} + \in_{it} \quad (12.4)$$

Model (12.1) and (12.2) information

Number of observations used	21
Model 1	Company patent valuation
Distribution	Normal
Predicted variable	*Company patent valuation*
Number of parameters	3
Scale	34.4208
Log likelihood	−104.10958
Model 2	Intangibles
Distribution	Normal
Predicted variable	*Total intangible assets*
Number of parameters	3
Scale	40.9666
Log likelihood	−107.76562

Vuong test

H_0: models are equally close to the true model

H_a: one of the models is closer to the true model

Vuong Statistic	Z	$Pr > \|Z\|$	Preferred model
Unadjusted	0.9551	0.3	*Company patent valuation*
Akaike adjusted	0.9551	0.3	*Company patent valuation*

Clarke sign test

H_0: models are equally close to the true model

H_a: one of the models is closer to the true model

Clarke statistic	M	$Pr \geqslant \|M\|$	Preferred model
Unadjusted	6.50	0.0072	*Company patent valuation*
Akaike adjusted	6.50	0.0072	*Company patent valuation*

Model (12.1) and (12.3) information

Number of observations used	21
Model 1	Company patent valuation
Distribution	Normal
Predicted variable	*Company patent valuation*
Number of parameters	3
Scale	34.4208
Log likelihood	−104.10958
Model 3	R&D capital (CLS)
Distribution	Normal
Predicted variable	*R&D capital* (*CLS*)
Number of parameters	3
Scale	22.2729
Log likelihood	−94.968479

Vuong test

H_0: models are equally close to the true model

H_a: one of the models is closer to the true model

Vuong statistic	Z	$Pr > \|Z\|$	Preferred model
Unadjusted	−2.21136	0.0345	*R&D capital* (*CLS*)
Akaike adjusted	−2.1136	0.0345	*R&D capital* (*CLS*)

Table VI.
Vuong and Clarke tests of patent valuation vs reported intangible assets and R&D capital value-relevance

(*continued*)

Clarke sign test

H_0: models are equally close to the true model

H_a: one of the models is closer to the true model

Clarke statistic	*M*	Pr⩾|*M*|	Preferred model
Unadjusted	−7.5000	0.0015	*R&D capital* (*CLS*)
Akaike adjusted	−7.5000	0.0015	*R&D capital* (*CLS*)

Model (12.1) and (12.4) information

Number of observations used	21
Model 1	Company patent valuation
Distribution	Normal
Predicted variable	*Company patent valuation*
Number of parameters	3
Scale	34.4208
Log likelihood	−104.10958
Model 4	*R&D capital* (*LS*)
Distribution	Normal
Predicted variable	*R&D capital* (*LS*)
Number of parameters	3
Scale	20.8909
Log likelihood	−93.623293

Vuong test

H_0: models are equally close to the true model

H_a: one of the models is closer to the true model

Vuong statistic	*Z*	Pr > |*Z*|	Preferred model
Unadjusted	−2.3808	0.0173	*R&D capital (LS)*
Akaike adjusted	−2.308	0.0173	*R&D capital (LS)*

Clarke sign test

H_0: models are equally close to the true model

H_a: one of the models is closer to the true model

Clarke statistic	*M*	Pr⩾|*M*|	Preferred model
Unadjusted	−7.5	0.0015	*R&D capital* (*LS*)
Akaike adjusted	−7.5	0.0015	*R&D capital* (*LS*)

Notes: *Price* is absolute close market price of common stock at financial year end; *BVE_ps* is fiscal year end common equity minus reported total intangible assets divided by number of common shares outstanding at fiscal year end; *net income_ps* is income before extraordinary items divided by number of common shares outstanding at fiscal year end; *company patent valuation_ps* is the company aggregate of future drug cash flows discounted at 0.11 to patent expiry or to 15 years post-approval divided by number of common shares outstanding at fiscal year end; *total intangible assets_ps* is reported total intangible assets at financial year end *t* divided by number of common shares outstanding at fiscal year end; *R&D capital (CLS)_ps* is Chan *et al.* (2001) estimation of company *R&D capital* divided by number of common shares outstanding at fiscal year end; *R&D capital (LS)_ps* is Lev and Sougiannis (1999) estimation of company *R&D capital* divided by number of common shares outstanding at fiscal year end. Annual pooled sample for financial years ended 2012 and 2013

Table VI.

discovery and development process (DiMasi *et al.*, 1991). For pharmaceutical companies and standard setters, the results support the recognition of internally generated intangible assets. Pharmaceutical companies are in a better position than the author to estimate future cash flows and company patent valuations are likely to be value-relevant.

The implication of the results for practitioners and users of financial statements is that the presentation of sales revenue information can assist the valuation of assets and the price discovery of stocks. In addition, the discounted cash flow method of valuing

intangible assets can be more useful in assessing the financial position of pharmaceutical companies than other methods of valuation The implication of the results for researchers is that intellectual capital reporting is a valuable area of research where asset measurement uses well-established quantitative methods.

The research and findings have a number of limitations. The patent valuations are dependent on cash flow, discount rate, and patent expiry assumptions and estimations. At the industry level, increases in pharmaceutical merger and acquisition activity may change the relative importance of internally generated and acquired intangible assets although internally generated intangibles will continue to be important.

Finally, one area of future research is to assess other capital market effects of the voluntary disclosure of intangible asset information such as reduced information asymmetry and cost of capital. The disclosure literature indicates a market reaction to credible commitments by companies to volunteer information. A second area of research is to use the value of reported assets and unreported assets of pharmaceutical companies to estimate the value of in-process R&D reflected in share price.

References

Aitken, M.L., Berndt, E.R. and Cutler, D.M. (2009), "Prescription drug spending trends in the United States: looking beyond the turning point", *Health Affairs*, Vol. 28 No. 1, pp. 151-160.

Alfredson, K. (2001), "Accounting for identifiable intangibles – an unfinished standard-setting task", *Australian Accounting Review*, Vol. 11 No. 2, pp. 12-22.

Andriessen, B. (2004), "IC valuation and measurement: classifying the state of the art", *Journal of Intellectual Capital*, Vol. 5 No. 2, pp. 230-242.

Barth, M.E. and Clinch, G. (1998), "Revalued financial, tangible, and intangible assets: associations with share prices and non-market-based value estimates", *Journal of Accounting Research*, Vol. 36, Supplement, pp. 199-233.

Barth, M.E. and Clinch, G. (2009), "Scale effects in capital markets-based accounting research", *Journal of Business Finance & Accounting*, Vol. 36 Nos 3-4, pp. 253-288.

Barth, M.E. and Kallapur, S. (1996), "The effects of cross-sectional scale differences on regression results in empirical accounting research", *Contemporary Accounting Research*, Vol. 13 No. 2, pp. 527-567.

Barth, M.E., Beaver, W.H. and Landsman, W.R. (2001), "The relevance of the value relevance literature for financial accounting standard setting: another view", *Journal of Accounting and Economics*, Vol. 31 No. 1, pp. 77-104.

Berndt, E.R. and Aitken, M.L. (2010), "Brand loyalty, generic entry and price competition in pharmaceuticals in the quarter century after the 1984 Waxman-Hatch Legislation", Working Paper No. 16431, NBER Working Paper Series, available at: www.nber.org/papers/w16431 (accessed 31 July 2012).

Bessen, J. (2008), "The value of US patents by owner and patent characteristics", *Research Policy*, Vol. 37 No. 5, pp. 932-945.

Boekestein, B. (2006), "The relation between intellectual capital and intangible assets of pharmaceutical companies", *Journal of Intellectual Capital*, Vol. 7 No. 2, pp. 241-253.

Catalfo, P. and Wulf, I. (2016), "Intangibles disclosure in management commentary regulation in Germany and Italy", *Journal of Intellectual Capital*, Vol. 17 No. 1, pp. 103-119.

Chan, L.K.C., Lakonishok, J. and Sougiannis, T. (2001), "The stock market valuation of research and development expenditures", *The Journal of Finance,* LVI No. 6, pp. 2431-2456.

Christie, A.A. (1987), "On cross-sectional analysis in accounting research", *Journal of Accounting and Economics*, Vol. 9 No. 3, pp. 231-258.

Clarke, K.A. (2001), "Testing nonnested models of international relations: reevaluating realism", *American Journal of Political Science*, Vol. 45 No. 3, pp. 724-744.

Dahmash, F.N., Durand, R.B. and Watson, J. (2009), "The value relevance and reliability of reported goodwill and identifiable intangible assets", *The British Accounting Review*, Vol. 41 No. 2, pp. 120-137.

Damodaran, A. (2009), *Damodaran on Valuation, Security Analysis for Investment and Corporate Finance*, 2nd ed., John Wiley & Sons, Hoboken, NJ.

DiMasi, J.A., Hansen, R.W. and Grabowski, H.G. (2003), "The price of innovation: new estimates of drug development costs", *Journal of Health Economics*, Vol. 22 No. 2, pp. 151-185.

DiMasi, J.A., Hansen, R.W., Grabowski, H.G. and Lasangna, L. (1991), "Cost of innovation in the pharmaceutical industry", *Journal of Health Economics*, Vol. 10 No. 2, pp. 107-142.

Dumay, J. (2016), "A critical reflection on the future of intellectual capital: from reporting to disclosure", *Journal of Intellectual Capital*, Vol. 17 No. 1, pp. 168-184.

Easton, P.D. and Sommers, G.A. (2003), "Scale and scale effect in market-based accounting research", *Journal of Business Finance & Accounting*, Vol. 30 No. 1, pp. 25-55.

Ely, K., Simko, P.J. and Thomas, L.G. (2003), "The usefulness of biotechnology firms drug development status in the evaluation of research and development costs", *Journal of Accounting Auditing and Finance*, Vol. 18 No. 1, pp. 163-196.

Gleason, K.I. and Klock, M. (2006), "Intangible capital in the pharmaceutical and chemical industry", *The Quarterly Review of Economics and Finance*, Vol. 46 No. 2, pp. 300-314.

Grabowski, H. (2002), "Patents and new product development in the pharmaceutical and biotechnology industries", working paper, Duke University Economics, Durham, NC, July, available at: www.econ.duke.edu/Papers/Other/Grabowski/Patents.pdf (accessed 1 August 2012).

Grabowski, H. and Vernon, J. (1990), "Returns and risks to pharmaceutical R&D", *Management Science*, Vol. 36 No. 7, pp. 804-821.

Grabowski, H., Vernon, J. and DiMasi, J.A. (2002), "Returns of research and development for 1990s new drug introductions", *Pharmacoeconomics*, Vol. 20 No. 3, pp. 11-29.

Grabowski, H.G., Kyle, M., Mortimer, R., Long, G. and Kirson, N. (2011), "Evolving brand-name and generic drug competition may warrant a revision of the Hatch-Waxman act", *Health Affairs*, Vol. 30 No. 11, pp. 2157-2166.

Griliches, Z. (1990), "Patent statistics as economic indicators: a survey", *Journal of Economic Literature*, Vol. 28 No. 4, pp. 1661-1707.

Hartmann, M. and Hassan, A. (2006), "Application of real options analysis for pharmaceutical R&D project valuation: empirical results from a survey", *Research Policy*, Vol. 35 No. 3, pp. 343-354.

Healy, P.M., Myers, S.C. and Howe, C.D. (2002), "R&D accounting and the tradeoff between relevance and reliability", *Journal of Accounting Research*, Vol. 40 No. 3, pp. 677-710.

Holthausen, R.W. and Watts, R.L. (2001), "The relevance of the value-relevance literature for financial accounting standard setting", *Journal of Accounting and Economics*, Vol. 31 Nos 1-3, pp. 3-75.

Hunter, L., Webster, E. and Wyatt, A. (2012), "Accounting for expenditure on intangibles", *Abacus*, Vol. 48 No. 1, pp. 104-145.

Lagrost, C., Martin, D., Dubois, C. and Quazzotti, S. (2010), "Intellectual property valuation: how to approach the selection of an appropriate valuation method", *Journal of Intellectual Capital*, Vol. 11 No. 4, pp. 481-503.

Lev, B. and Schwartz, A. (1971), "On the use of the economic concept of human capital in financial statements", *The Accounting Review*, Vol. 46 No. 1, pp. 103-112.

Lev, B. and Sougiannis, T. (1999), "Penetrating the book to market black box: the R&D effect", *Journal of Business Finance & Accounting*, Vol. 26 Nos 3-4, pp. 419-449.

Lev, B. and Zarowin, P. (1999), "The boundaries of financial reporting and how to extend them", *Journal of Accounting Research*, Vol. 37 No. 2, pp. 353-385.

Mehralian, G., Rasekh, H.R., Akhavan, P. and Sadeh, M.R. (2012), "The impact of intellectual capital efficiency on market value: an empirical study from Iranian pharmaceutical companies", *Iranian Journal of Pharmaceutical Research*, Vol. 11, pp. 195-207.

Petty, R. and Guthrie, J. (2000a), "Intellectual capital literature review", *Journal of Intellectual Capital*, Vol. 1 No. 2, pp. 155-176.

Petty, R. and Guthrie, J. (2000b), "Intellectual capital: Australian annual reporting practices", *Journal of Intellectual Capital*, Vol. 1 No. 3, pp. 241-251.

Pitkethly, R. (1997), "The valuation of patents", Working Paper No. 21/97, The Judge Institute of Management Studies, Cambridge.

Rosenthal, M.B., Berndt, E.R. and Donohue, J.M. (2002), "Promotion of prescription drugs to consumers", *New England Journal of Medicine*, Vol. 346 No. 7, pp. 498-505.

Sadan, S. and Auerbach, L.B. (1974), "A stochastic model for human resource evaluation", *California Management Review,* Vol. XVI No. 4, pp. 24-31.

Schaper, S. (2016), "Contemplating the usefulness of intellectual capital reporting: reasons behind the demise of IC disclosures in Denmark", *Journal of Intellectual Capital*, Vol. 17 No. 1, pp. 52-82.

Shortridge, R.T. (2004), "Market valuation of successful versus non-successful R&D efforts in the pharmaceutical industry", *Journal of Business Finance & Accounting*, Vol. 39 Nos 9-10, pp. 1301-1325.

Vuong, Q.H. (1989), "Likelihood ratio tests for model selection and non-nested hypotheses", *Econometrica*, Vol. 57 No. 2, pp. 307-333.

Wines, G.F. and Ferguson, C. (1993), "An empirical investigation of accounting methods for goodwill and identifiable intangible assets: 1985 to, 1989", *Abacus*, Vol. 29 No. 1, pp. 90-105.

Wyatt, A. (2008), "What financial and non-financial information on intangibles is value-relevant? A review of the evidence", *Accounting and Business Research*, Vol. 38 No. 3, pp. 217-256.

Xu, B., Magnan, M. and Andre, P. (2007), "The stock market valuation of R&D information in biotech firms", *Contemporary Accounting Research*, Vol. 24 No. 4, pp. 1291-1318.

Yang, Y. (2007), "The value-relevance of nonfinancial information: the biotechnology industry", *Advances in Accounting*, Vol. 23, pp. 287-314.

Zacks Investment Research, Industry Outlook (2012), "Pharma & biotech stock outlook – August 2012", available at: http://www.zacks.com/commentary/22822/pharma-biotech-stock-outlook-aug-2012; http://community.nasdaq.com/News/2012-08/pharma-biotech-stock-outlook-aug-2012-industry-outlook%282%29.aspx?storyid=162814 (accessed 9 August 2012).

Further reading

US Congress, Office of Technology Assessment (1993), *Pharmaceutical R&D: Costs, Risks, and Rewards*, OTA-H-522, US Government Printing Office, Washington, DC.

Corresponding author

Mark Russell can be contacted at: m.russell@business.uq.edu.au