American Journal of Medical Research 3(2), 2016
pp. 141–151, ISSN 2334-4814, eISSN 2376-4481

LOW R&D EFFICIENCY IN LARGE PHARMACEUTICAL COMPANIES

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ABSTRACT. Large pharmaceutical companies will face serious challenges in the future when several of their blockbuster drugs run out of patents, and meanwhile a growing political pressure to stop the fast increase in health care expenditures has emerged. The recent wave of mergers and acquisitions (M&A) within the industry can be seen as an effective means to reduce costs and compensate for the reduced earnings from patented drugs. The paper examines the main development in expenditure on research and development (R&D) and number of patents in the industry with a focus on the role of company size. The analysis builds on a data set containing information of both patents and R&D expenditure from the world's top 90 largest pharmaceutical companies, as well as their account data from 2002 to 2013. The empirical part estimates the firm size effect on R&D efficiency and the amount of investment allocated to R&D. Fixed effects estimation models have been applied to control for differences in firm characteristics. We find significantly lower innovation activities in large companies with low innovation productivity as well. The M&A strategy of the large pharmaceutical companies may have been their wise move to catch up on new drugs and revenues.

Keywords: drug innovation; patents; R&D efficiency; company size-effects; M&A strategy; pharmaceutical R&D

How to cite: Madsen, Erik Strøjer, and Yanqing Wu (2016), "Low R&D Efficiency in Large Pharmaceutical Companies," *American Journal of Medical Research* 3(2): 141–151.

Received 21 July 2016 • Received in revised form 5 September 2016
Accepted 5 September 2016 • Available online 20 September 2016

1. Introduction

The pharmaceutical companies will face serious challenges in the future when several of the blockbuster drugs run out of patent, and the innovation of new ones seems to be lagging. The growing political pressure to reduce the fast increase in health care expenditures is also a challenge. New regulations have already been introduced which facilitate the approvals and prescriptions of generic drugs. This reduces the return from innovation of new drugs. The decreasing productivity of R&D spending and the tough market conditions following the tighter government regulation already reduced the speed of innovation and created challenges for the industry, according to Price Waterhouse (2015).

Low productivity of R&D within the pharmaceutical industry was already pointed out by Grabowski (2004), who found a significant decrease in the introduction of new drugs and firms' incomes from new drug introduction in the sixties and seventies. The steep increase in R&D expenses in the eighties where the R&D share of sales double to 14% is seen as a result of higher expected returns to R&D based on the past introduction of new drugs and at the same time a fall in the productivity of R&D expenses – see also Grabowski & Vernon (2000). We extend their analysis by focusing on the individual pharmaceutical companies and find the problem with low R&D productivity related to the large companies.

The increasing competition in the market place and reduced earnings from patented drugs may have triggered the recent wave of mergers and acquisitions (M&A) within the pharmaceutical industry. When running out of patented and highly priced drugs, the pharmaceutical companies find themselves overstaffed with excess capacity in their sales and marketing department. As an alternative to downsizing, they find it more attractive to buy new drugs through the M&A strategy as it is both faster and cheaper than to develop new drugs. There is some evidence that pharmaceutical companies use M&A as a strategy to fill the gaps in their pipeline of new and protected drugs – see Higgins & Rodriguez (2006), Danzon et al. (2007), Hassan et al. (2007), and Grabowski & Kyle (2008).

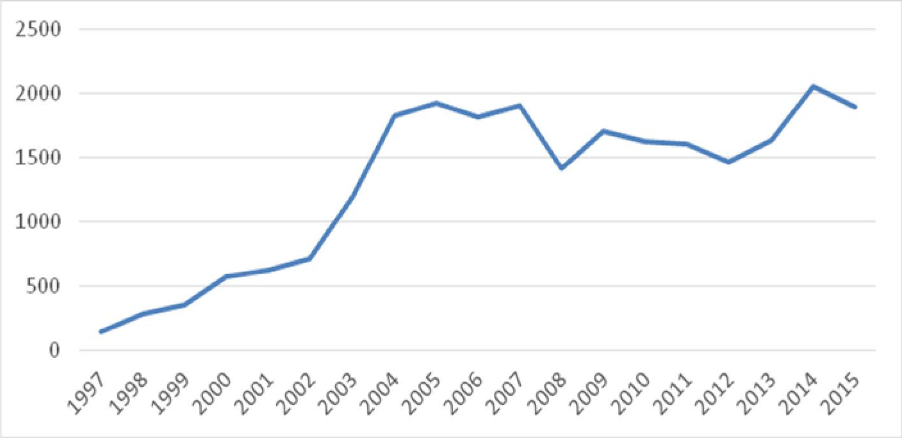
Running out of blockbusters and low hanging fruits, the pharmaceutical industry seems to face a real challenge in the future. In this paper, we highlight the development in the performance of the large pharmaceutical companies in the last decade with a focus on the productivity of their innovation activities. Our database covers 90 of the largest pharmaceutical companies with account information on their earnings, and we have added information on their expenses on R&D and number of patents. We find large productivity problems of innovation activities in the industry when using number of patents as an output measure of innovation. The low innovation productivity is highly related to company size. It can explain why the larger companies are eager to acquire new innovative companies. This restructuring of the pharmaceutical industry through M&A activities can compensate for the lagging productivity of innovation in large companies.

The next section discusses some effects of M&A and presents the empirical evidence from the pharmaceutical industry. Section 3 presents the data used in this paper and discusses the time and company size dimension of our data. The empirical tests are presented in Section 4 and finally, Section 5 concludes the paper.

2. Restructuring of the Industry

Restructuring of the pharmaceutical industry is illustrated in figure 1 which pictures the development in the number of M&A in the period from 1997 to 2015. There is a clear increasing trend in the M&A activities during the period and some business cycles too. The transaction value of the known M&A deals has also increased and peaked in 2015 with 748 billion EUR, where Pfizer's acquisition of Allergan has created the world's largest drug company. Also, the number of M&A deals is much higher compared with other industries, and moreover, it underlines the challenges of innovation and expected earnings in this industry.

Figure 1 Number of M&A deals with known values, 1997 to 2015



Note: Number of M&A within the manufacture of pharmaceutical preparations, NACE rev. 2.
Source: Zephyr Database

Abnormal return from M&A is proved through a lot of event studies based on share prices, where they observe the return in a short period or window – see Andrea et al. (2001) for a general survey of event studies of M&A. But what are the sources of the abnormal return? The underlying sources of gains from mergers have not been identified and most of the evidence concerning this issue is more case-based.

Economic theory points to two main effects of M&A on company performance. First, the market power hypothesis predicts less competition in the market with a horizontal merger. The conditions for collusion between the reduced numbers of suppliers become more favorable and higher market price and profit margins seem likely.

The second effect comes from the possibility of reducing the costs in the merge companies due to duplicating activities in the two companies. The cost saving could emerged in many departments such as general management, production facilities, R&D, sales and marketing, etc. Most of these synergies are related to the size of the company, as the company can grow by a merger without duplicating the activities. However, cost saving can also come from reducing agency costs if the acquirer takes over a firm with an inefficient management, and implements more market discipline.

What is special about the pharmaceutical industry? First of all, it is heavily research-based. Research is very risky and the costs come before the return. This intangible investment is difficult to finance in the capital market. Companies therefore have to use internal finance by retained earnings or go to the equity market. This creates some economics of scale and barriers to entry. If research succeeds in a new drug, it has to be approved by the government for health reasons and drug safety. The approval has been more tough in recent years, as the pharmaceutical companies not only have to prove the positive health care effects without negative side effects, but they also have to approve that the effects are superior compared with the drugs already on the market. The requirements of more detailed evidence and specifications for new drugs are expensive and time consuming and have reduced the effective patent protection period from the scheduled 20 years to less than 10 years on average.

Secondly, sales and marketing play an important role in the pharmaceutical industry and are important barriers against entry of small firms. Sales and marketing activities are very costly, as advertising is highly restricted, and pharmaceutical companies have to approach hospitals and doctors by sales agents. It takes large fixed costs to cover the whole market by sales agents. Therefore, large pharmaceutical companies have competitive advantages compared to smaller firms as they have already covered most of the market, and they can add another drug to their product portfolio more cheaply.

There are only a few empirical studies concerning the effects of mergers in the pharmaceutical industry, and they found positive effects on average. The event studies examined movement in share price after the announcement of the merger, and they found evidence that the acquisitions on average realize significant positive returns – see Higgins & Rodriguez (2006), Andrea et al.

(2001) and Danzon et al. (2007). However, Hassan et al. (2007) found no abnormal return to acquire.

Danzon et al. (2007) studied the determinants of M&A activities in the pharmaceutical industry. They found excess capacity due to anticipated patent experience and gaps in the product pipeline as main factors in motivating M&A. Small firms, on the other side, seem to choose an exit strategy motivated by financial problems. Mitchell and Mulherin (1996) studied the waves of M&A and its clustering on specific industries. They found that shocks from public deregulation play an important role.

Most of the empirical studies of the effects on mergers use an event method, and this method normally gives only limited information concerning the source behind the positive return from mergers. This gap can be filled by including more information of the companies, and evidence arising from accounting-based data seems obvious. Only a few empirical studies have used plant-level data – see McGuckin and Nguyen (1995) and Schoar (2002).

As overcapacity in sales and marketing is a main challenge for the large pharmaceutical companies, we will focus on their innovation activities in this study by using innovation and accounting data. Many M&A activities in this industry are probably a result of low innovation activity and gaps in the product pipeline. However, the smaller companies also have to agree in an acquisition. From their standpoint, the merger is often a perfect match, as they need the sales and marketing staff to bring their new products to the market. They also need research funding for clinical trials and finally have them approved by the authorities. Hence M&A is often the end result of a corporation between the companies. The acquisitions often start with a funding agreement with the smaller companies to finance their clinical research by offering equity capital and taking a small share of the companies.

3. Data and Estimation Methods

Our database holds innovation information from 94 of the largest pharmaceutical companies from 2002 to 2013. The data has been retrieved from the Orbis Database and the sample companies cover 77.5% of the turnover in the industry. Table 1 lists some descriptive statistics of the variables used in the analysis where companies not reporting R&D are excluded. The average turnover for the companies is about 9 billion USD and they take out 1300 patents per year. On average, they earned close to 2 billion USD per year and they are able to finance their total R&D expenses from their earnings.

Table 1 Descriptive statistics

Variables	Observations	Mean	Standard deviation
Revenue	811	9.160	14.021
EBIT	811	1.928	3.509
Total asset	811	16.945	29.526
R&D	811	1.299	2.101
No. of patents	630	634.8	1003.6

Note: Revenue, EBIT, total asset and R&D are measured in billion USD.
Source: The Orbis company database.

Table 2 focuses on their performance over time. Despite the large number of M&A in the period shown in figure 1, the concentration index for these large companies has decreased in the period from 0.050 to below 0.040 or by 20%. This indicates that the distribution of firm size in the industry has become more even over the period, so the M&A activities may be of benefit to the growth of smaller companies or they have had a higher organic growth for other reasons. There seems to be no trend in the EBIT share and the share of revenue invested in R&D. However, the patent share has dropped dramatically in the period from about 0.10 to below 0.07 per million USD. As a result, the productivity of the R&D investment listed in the last column has decreased too.

Table 2 Development in performance, 2002 to 2013

Year	Herfindahl Index	EBIT Revenue share	R&D Revenue share	Patent Revenue share	Patent R&D share
2002	0.050	0.142	0.151	0.101	0.935
2003	0.050	0.128	0.168	0.098	0.887
2004	0.048	0.142	0.150	0.092	0.834
2005	0.046	0.149	0.141	0.089	0.819
2006	0.045	0.148	0.145	0.090	0.829
2007	0.043	0.121	0.164	0.074	0.711
2008	0.040	0.135	0.170	0.078	0.882
2009	0.038	0.104	0.199	0.072	0.740
2010	0.039	0.109	0.174	0.066	0.629
2011	0.039	0.171	0.121	0.067	0.654
2012		0.160	0.123		
2013		0.161	0.121		
Average		0.139	0.153	0.082	0.786

Note: The Herfindahl-Hirschman index is calculated as the sum of squared market shares for the 90 largest companies. Patent revenue share calculated as number of patent per million USD in revenue. Patent R&D share calculated as number of patent per million USD R&D expenses.
Source: The Orbis company database.

The size of the companies varies a lot even in our sample covering the 90 largest companies in the industry. To examine how size affects the performance of companies, table 3 shows their performance classified according to revenues. Small companies have revenues less than 2 billion USD, large companies have revenues above 25 billion USD, and the development in the period shows two things. First, large pharmaceutical companies have higher profit, with the EBIT share of their revenues close to three times higher than smaller companies. The higher profit is earned with the same capital basis, as the capital output ratio does not change much with company size. Second, the productivity of innovation is significantly higher for the smaller companies. Compared with the larger companies, they collect twice as many numbers of patents per dollar R&D spending, and they also spend about 20% more on R&D relative to their revenue.

Table 3 Performance according to firm size

Variables	Large	Medium	Small	All
Number of Observations	161	296	354	811
EBIT share	0.223	0.161	0.082	0.139
Total asset share	1.894	1.683	1.837	1.792
R&D share	0.150	0.122	0.179	0.153
No. of patents share	0.067	0.069	0.098	0.082
Patent per R&D share	0.497	0.582	1.067	0.786

Note: All calculations based on revenue share. Patent share calculated as number of patents per million USD in revenue.
Source: The Orbis company database.

4. Does Company Size Matter?

Decreasing productivity of innovation, more tough regulations of both the approval of new drugs and generics' price setting have been a grave challenge to the pharmaceutical industry. As discussed above, there is some evidence that the industry has responded to these challenges by a strategy of M&A – see Higgins & Rodriguez (2006), Danzon et al. (2007), Hassan et al. (2007), and Grabowski & Kyle (2008). These event studies found a positive return to shareholders of the acquiring company around the announcement of the acquisitions. The higher value of the combined company predicted by the share market could be based on scale effects on R&D and sales & marketing as well. We will test this in the following.

Scale effects on innovation

To examine the scale effects on innovation, we estimated the scale elasticity of R&D and the number of patents with respect to total assets of the company. Equation (1) shows the estimated model with a log transformation of variables. I_{ji} is the innovation measure where j is either R&D or number of patents for company i. We measure size with total asset TA_i for company i. δ_i is a fixed effect for company i, which picks up differences in costs efficiency and accounting practices for the individual pharmaceutical company.

$$\text{Log}(I_{ji}) = \alpha_j + \beta_j \text{ Log}(TA_i) + \delta_{ji} \qquad (1)$$

The parameter of interest here is the scale elasticity β_j. If it is equal to one, there is a full proportionality between the innovation measure and company size, hence no scale effect is present. If the scale elasticity is less than one for R&D, it can be the result of economies of scale in the innovation process as mentioned above. But it could also be the result of different innovation policies between small and large companies. Table 4 shows the estimated elasticities for R&D and number of patents.

Table 4 Estimation of time and size elasticities for R&D and number of patents

Dependent variables	**R&D (log)**		**Number of patents (log)**	
Constant	84.161** (20.051)	Fixed effect companies	80.018* (29.830)	Fixed effect companies
Year	-0.0444** (0.0100)		-0.0345* (0.0149)	
Total asset (log)	1.1426** (0.0224)	0.7284** (0.0208)	0.9284** (0.0284)	0.6247** (0.0350)
R-square Observations	0.7666 811	0.9782 811	0.6419 606	0.9503 606

Note: One and two stars indicate where the coefficients are different from zero at a significant level of 5 and 1% respectively.
Source: The Orbis company database.

The OLS estimation for R&D expenditures shows a significant decrease of R&D investment in the period of 4.4% p.a. and a size elasticity of 1.14 for these companies which is significantly different from both zero and one. This estimate offers some evidence of the challenges for the industry with decreasing investment in R&D over time when correcting for company size. The overall stability in the R&D investment in the period 2002–2013 is therefore a result of the restructuring of the pharmaceutical industry with a switch to larger companies, which have a higher R&D share. Controlling for company heterogeneity, however, the fixed effect estimation reduces the size elasticity to only 0.72. The low within-company size effects for R&D can be interpreted as evidence for economics of scale in R&D, if the patent activity does not decrease with company size also. This is the topic for the next estimations.

The estimation results for the number of patents display a quite different picture of the innovation process in large and small companies. The estimated size elasticity for patents is significantly lower than one. This indicates that smaller companies produce more patents relative to their size. As patent is an output measure of their innovation activities, this result confirms that the larger companies are less innovative compared to the smaller companies. This result is further strengthened by the fixed effect estimation with a size elasticity of just 0.62. Consequently, larger companies have a much higher risk of running out of new drugs compared to the smaller companies.

As the larger companies spend more on R&D compared to the smaller companies, it implies lower innovation productivity for the larger companies as also verified in table 3, and we will now turn to this topic into more detail.

Productivity of R&D

To examine the innovation productivity further, we estimated the scale elasticity of patents with respect to the expenses on R&D, which equation (2) shows the estimated model with a log transformation of variables. PAT_i is the number of patents and RD_i is R&D expenses for company i. β is the productivity coefficients for R&D. If β is equal to one, there are constant returns to scale in R&D investment. If β is larger than one there exists economies of scale in R&D activities. δ_i is a fixed effect for company i, which picks up differences in innovation efficiency, accounting practices and other characteristics for the individual pharmaceutical company.

$$\text{Log}(PAT_i) = \alpha + \beta\, \text{Log}(RD_i) + \delta_i \qquad (2)$$

Table 5 presents the estimation results of elasticities for R&D productivity. The estimated productivity coefficients are significant below one in both equations. The result does not prove any economies of scale in R&D with respect to the number of patents; the within-company size effects of R&D investment are significantly lower than the cross-company effects. These large diseconomies of scale for R&D investment add new evidence to the problems that large pharmaceutical companies have to face.

Table 5 Estimation of elasticities for R&D productivity

Dependent Variables	**Number of patents (log)**	
Constant	28.213 (26.791)	Fixed effect companies
Year	-0.0168 (0.0134)	
R&D (log)	0.8379** (0.0221)	0.6560** (0.0351)
R-square Observations	0.7082 606	0.9520 606

Note: One and two stars indicate where the coefficients are different from one at a significant level of 5 and 1% respectively.
Source: The Orbis company database.

The diseconomies of scale in innovation may cause a threat to large research-based companies in the pharmaceutical industry. To examine this problem further, we run the size estimation in equation (1) for R&D productivity measured by the number of patents per million USD. Table 6 lists the estimation results. The time trend in innovation productivity is negative with 1.66% p.a., but it is not significant. The size elasticity, on the other hand, is significant with a large negative value of -0.205 for the within-company effects. Companies with double size therefore have a 20.5% lower patent productivity. The message from this result is that the low productivity of innovations is mainly related to the larger companies in the industry.

Table 6 Estimation of time and size effects on R&D productivity

Dependent variables	**Patents per R&D (log)**	
Constant	34.941 (27.419)	Fixed effect companies
Year	-0.0166 (0.0137)	
Total asset (log)	-0.1494** 0.0261)	-0.2050** (0.0232)
R-square Observations	0.0570 606	0.8335 606

Note: One and two stars indicate where the coefficients are different from one at a significant level of 5 and 1% respectively.
Source: The Orbis company database.

Of course, this result depends on the measurement of productivity. The number of patents is not the only measure of output, as a new drug can be evaluated by different medical science methods. Further, an invention can be split up into several patents, and the tradition may vary between the companies. However, if this habit does not correlate with firm size, the estimated size effects may still be reliable and verify that the larger pharmaceutical companies have problems with efficiency in new drugs development and the gap in portfolio drugs.

5. Conclusion

The pharmaceutical companies will face serious challenges in the future where several of the blockbuster drugs run out of patents and there is a growing political pressure to cut down the fast expanding health care expenditures. The recent wave of mergers and acquisitions within the industry can be seen as a means to reduce R&D costs and compensate for the reduced earnings from patented drugs.

The paper examines the main development in the expenditure on R&D and the number of patents in the pharmaceutical industry with a focus on the role of company size. The analysis builds on a database containing information on both patents and R&D expenditure from the world's top 90 largest pharmaceutical companies, and their sales revenue, earnings, and total assets from 2002 to 2013. The estimation verifies a size elasticity to fill patents significant below one. This diseconomy of scale in the companies' innovation activities is related to a significantly lower innovation productivity in large pharmaceutical companies.

The diseconomy of scale in the innovation process creates problems for the large pharmaceutical companies to fill the holes in their portfolio of drugs when the drugs run out of proprietary. The restructuring of the pharmaceutical industry through a merger and acquisition strategy may have been that large pharmaceutical companies move to catch on new drugs and spectacular revenues.

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