R&D Productivity and M&A in the Pharmaceutical and Biotech Industries

By

Khushali Upadhyay

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Professor Marti G. Subrahmanyam — Professor Deepak Hegde

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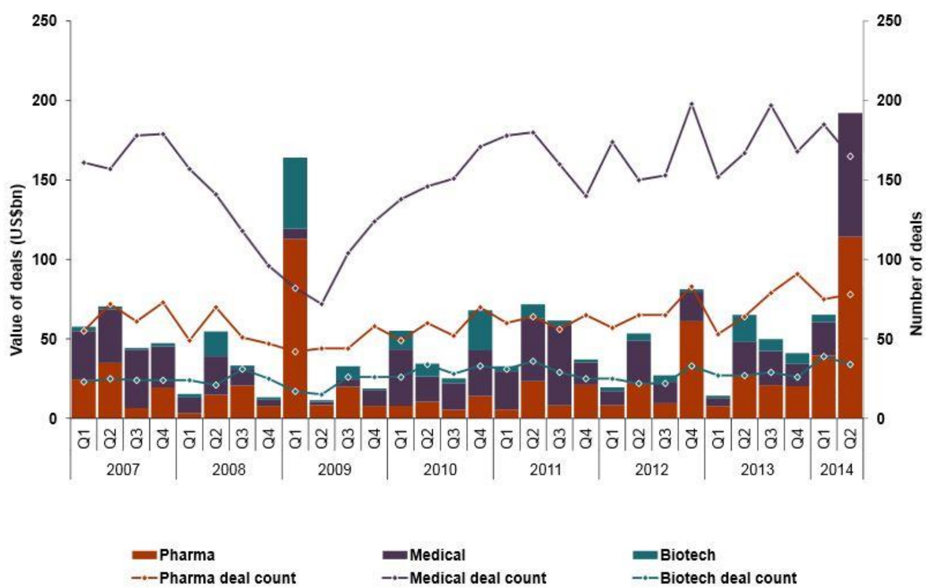
I. Introduction

Mergers and acquisitions (M&A) have been a source of growth for many companies historically. Generally, the long-term motivation for M&A is to increase profits and shareholder wealth.[1] However, there is an ongoing debate on whether growing through M&A actually creates value for the acquiring firm's shareholders.[2] The pharmaceutical and biotechnology (biopharma) industry is one that has experienced much consolidation through mergers in recent years, especially with the patent cliff and the shrinking pipelines. Companies are attempting to curb the decline in revenues and supplement the internal growth present by acquiring the pipelines of smaller biotech firms, which would replace the loss due to patent expiration.[3] 2014 has specifically been a very big year for healthcare M&A, as seen in Figure 1. Smaller firms have

Figure 1: Trend in M&A Transactions in the Healthcare Space



Source: Merger Market, Global Pharma, Medical, & Biotech Trend Report: H1 2014 (2014).

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[1] Gugler, K., Mueller, D.C., Yurtoglu, B.B., Zulehner, C. The Effects of Mergers: an International Comparison. *International Journal of Industrial Organization*. 21 (5), 625-653 (2003).
[2] Bruner, R. F. Does M&A Pay? A Survey of Evidence for the Decision-Maker. *Journal of Applied Finance.* 12 (1), 48-68 (2002).
[3] Jarvis, L. M. Pharmaceuticals: big firms will fight the patent cliff. *Chemical and Engineering News.* 88 (2), 17 (2010)

also been actively engaged in M&A, either to make up for lack of capital or as an attractive exit strategy.[4] An analysis of research and development (R&D) productivity is vital to determine a biopharma company's future profit and value. This paper empirically examines both how R&D productivity has changed over between the years of 1999 and 2013 as well as the argument that M&A transactions improve R&D productivity for the acquiring firm. There is very little empirical analysis on the R&D productivity due to the fact that there are many different formulaic interpretations as well as the difficulty of predicting the variables required for calculation. However, this is a critical aspect when trying to determine the value of M&A transactions in the pharmaceutical and biotech industries. Given that there is a focus on R&D productivity in these companies, the analysis will be able determine if using M&A is a sound business strategy. It allows for comparison between internal R&D spend versus investment in other companies through M&A activity.

The paper is organized as follows. Section 2 outlines the current literature about the decline of R&D productivity. Section 3 summarizes trends in M&A and the impact M&A can have on R&D expense. Section 4 displays the data and methodology followed by the regressions and results in Section 5. Conclusions are presented in Section 6.

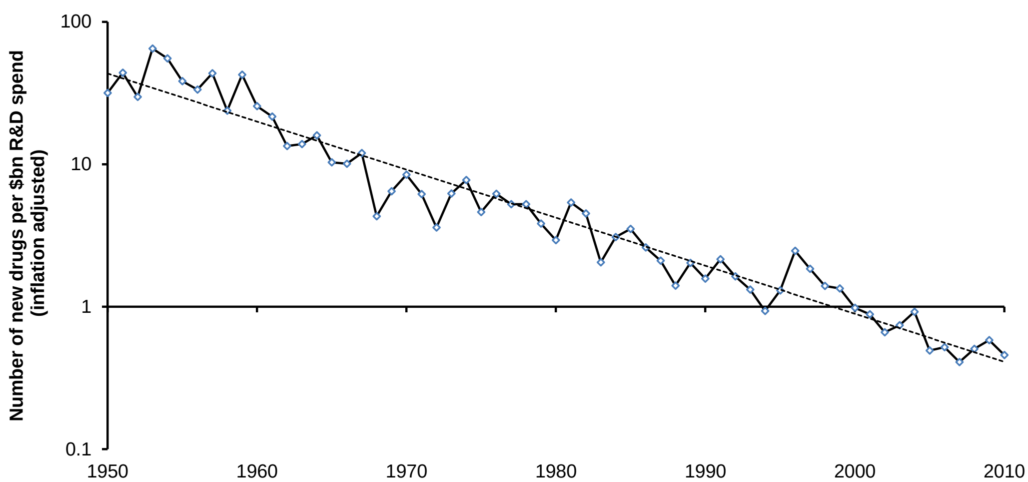
II. Decline of R&D Productivity

There are two main types of costs for drug development – out of pocket costs and time costs. In 2003, the Tufts Center for the Study of Drug Development (CSDD) estimated that it cost approximately $802 million to develop and achieve marketing approval for the drugs. This is

[4] Danzon, P.M., Epstein, A., Nicholson, S. Mergers and Acquisitions in the Pharmaceutical and Biotech Industries. *Managerial and Decisions Economics*. 28, 307-328 (2007).

equivalent to $1,044 million 2013 dollars. An update on the study shows that the average cost to develop a new drug has risen to $2,558 million in 2014. There has been clear increases in R&D expense per year even though the number of FDA approvals for new molecular entities (NMEs) each year has remained fairly stable.[5] [6] This calls to attention the overall R&D productivity of the industry. However, it is difficult to calculate R&D productivity because of the inability to measure many of the variables that can impact the value of R&D. It is a function of the work in process, the probability of technical success, and the overall value of the drug by the cost and the cycle time.[7] Another way to understand the function is by comparing outputs to inputs. The number of NMEs created is a function of the change in the probability of success of the research projects as well as the change in the number of new projects started each period.[8]

Figure 2: Trend in Pharmaceutical R&D Productivity



[5] DiMasi, J.A, Hansen, R.W., Grabowski, H.G. The Price of Innovation: New Estimates of Drug Development Costs. *Journal of Health Economics*. 22 (2), 151-185 (2003).
[6] DiMasi J.A. Pharmaceutical R&D Performance by Firm Size: Approval Success Rates and Economic Returns. *American Journal of Therapeutics*. 21 (1), 26-34 (2014).
[7] Paul, S.M., Mytelka, D.S., Dunwiddie, C.T., Persinger, C.C., Munos, B.H., Lindorg, S.R., Schacht, A.L. How to improve R&D Productivity: The Pharmaceutical Industry's Grand Challenge. Nature. 9, 203-214 (2010).
[8] Pammolli, F., Magazzini, L., Riccaboni, M. The Productivity Crisis in Pharmaceutical R&D. *Nature Drug Discovery*. 10, 428-438 (2011).

Scannell, et. al. (2012) shows the decline in productivity in terms of the number of FDA approvals per billion US$ spent and describes this phenomenon as “Eroom’s Law”. Figure 2 shows the visible declining trend which the paper attributes to four different problems in the industry, two of which are the “Better than the Beatles” problem and the “Cautious Regulator” problem.[9] In the music industry, if each new top song needed to be better than the Beatles, there would be very few songs actually produced. However, in the biopharma industry, there has been an overall broadening and advancement of the drugs already on the market through the improvement in the scientific knowledge and research available to the public. Each new discovery needs to further develop the current understandings that are in place, which aligns with the idea that the “low-hanging fruit” has already been picked. Any additional advancement requires much more investment in terms of time and capital.[10] In order to offset these costs, R&D spend is targeted towards more unfamiliar targets. Though the projects have a lower probability of success, the untapped markets allow for a higher potential return.[11] One manifestation of this movement towards riskier projects can be seen in the growth of orphan drug development. Orphan drugs are focused on rare diseases where there are few or no treatment options.[12] As shown in Figure 3, there has been a visible growth in the number of orphan products that have been approved every year with a 53% growth in 2014 from 2013. The percentage of total FDA approvals that have been given the orphan drug designation has also increased.[13]

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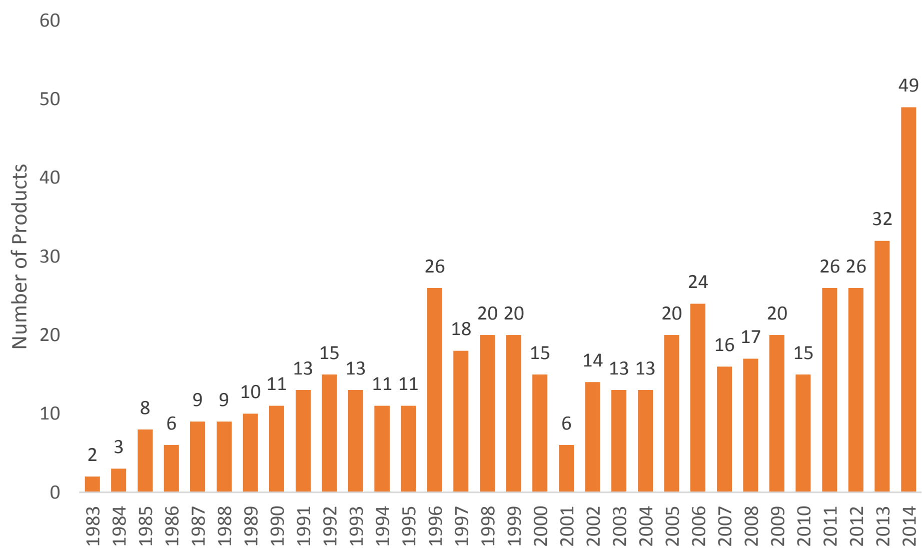
[9] Scannell, J.W., Blanckley, A., Boldon, H., Warrington, B. Diagnosing the decline in pharmaceutical R&D Efficiency. *Nature Drug Discovery*. 11, 192-200 (2012).
[10] Kraus, C.N. Low Hanging Fruit in Infectious Disease Drug Development. *Current Opinion in Microbiology*. 11 (5), 434-438 (2008).
[11] Pammolli, F., Magazzini, L., Riccaboni, M. The Productivity Crisis in Pharmaceutical R&D. *Nature Drug Discovery*. 10, 428-438 (2011).
[12] Cote, T., Kelkar, A., Xu, K., Braun, M.M., Philips, M.I. Orphan Products: An Emerging Trend in Drug Approvals. *Nature Reviews Drug Discovery*. 9, 84 (2010).
[13] Karst, K. R. The 2014 Numbers are In: FDA’s Orphan Drug Program Shatters Records. *FDA Law Blog – Hyman, Phelps & McNamara, P.C.* (2015).

Figure 3: Number of Approved Orphan Products per Year



The scientific and technological advancement in the biopharma space gives rise to the problem of a cautious regulator. The FDA regulatory body has become more stringent on its requirements for FDA approval, especially in terms of safety and efficacy, since there are already treatments available. Though this adds additional cost to the drug development process, it is adding value to societal needs.[14] The declining productivity in the industry aligns with the increase in M&A transactions within the recent years.

III. Impacts of M&A on R&D

There has been considerable research done on whether M&A transactions actually create value for the shareholders of the acquiring firm but few have actually shown significant gains by the acquiring firm.

[14] Scannell, J.W., Blanckley, A., Boldon, H., Warrington, B. Diagnosing the decline in pharmaceutical R&D Efficiency. *Nature Drug Discovery*. 11, 192-200 (2012).

Mergers can be horizontal, vertical, or conglomerate which all have different motivations. The rationale behind the action can vary from efficiency related reasons (economics of scale or synergies), to market power and discipline, to diversification or management goals.[15] The biopharma industry generally has a more specific range of M&A goals. The consolidation of the industry not only allows for a larger capital base for development, but also allows for more knowledge to be exchanged among the merged entities with the possibility of generating new ideas.[16] Therefore, the probability of pursuing an M&A transaction is positively related to the overall "desperation" of the acquiring firm prior to the transaction. The level of desperation is determined by the change in the weighted value of a company's pipeline products immediately prior to the transaction occurring. If the company is experiencing deteriorating pipeline quality and sales, they have a higher probability of engaging in M&A activity.[17]

A key determinant of transaction value to shareholders is R&D expense. Depending on the situation, R&D inputs can either increase or decrease as a consequence of M&A. A few papers argue that there is a negative effect on overall R&D investment and the R&D outputs due to acquisitions. However, the lower investment may be due to the removal of duplicate expenditures or through realizing other cost-related synergies.[18] [19] On the other hand, R&D investments can increase if the M&A transaction allows the acquiring firm to achieve economies

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[15] Andrade, G., Mitchell, M., Strafford, E., New Evidence and Perspectives on Mergers. *Journal of Economic Perspectives*. 15, 103-120 (2001).
[16] Andrade, G., Stafford, E., Investigating the Economic Role of Mergers. *Journal of Corporate Finance*. 10, 1-36 (2004).
[17] Higgins, M.J., Rodriguez, D., The Outsourcing of R&D through Acquisitions in the Pharmaceutical Industry. *Journal of Financial Eocnomics*. 80, 351-383 (2006).
[18] Hitt, M.A, Hoskisson, R.E., Ireland, R.D., Harrison, J.S., Effects of Acquisitions on R&D Inputs and Outputs. *Academy of Management Journal*. 34 (3), 693-706 (1991).
[19] Ornaghi, C., Mergers and Innovation in Big Pharma. *International Journal of Industrial Organization*. 27, 70-79 (2009).

of scale in downstream development, manufacturing and marketing related activities, which can lead to greater resources available for R&D investment. Thus, the effect of M&A on both R&D investments and R&D productivity can negative, positive, or non-existent.[20] There is little empirical analysis regarding how R&D productivity changes due to M&A and whether or not M&A create value for the acquiring firm through the effects they have on R&D and R&D productivity.

IV. Data & Methodology

The company set was constructed by including all companies worldwide that are publicly listed and classified by the Global Industry Classification Standard (GICS) as Pharmaceuticals or Biotechnology companies. The GICS codes that correspond to this are 3510 and 3520. A set of companies was created for each year since 1999. Identifier and market capitalization information for these companies were obtained from Bloomberg. Annual financial information was obtained from COMPUSTAT. The financials for international companies were converted to US$ using the applicable exchange rate for the last trading day of each year. These exchange rates were also obtained through Bloomberg. The data was scrubbed to only include the data points that have financial information for revenues, research and development expense, and net income. Additionally, four data points were removed as outliers (Table 1). Observations with negative revenues were also removed (Table 2). This leaves a final dataset of 8,407 firm-year observations with 1,071 firms. The sampling frame for this study is thus all publicly-listed R&D performing firms in the pharmaceutical and biotechnology industries.

[20] Cassiman, B., Colombo, M.G., Garrone, P., Veugelers, R., The Impact of M&A on the R&D Process – An Empirical Analysis of the Role of Technological- and Market-Relatedness. *Research Policy*. 34, 195-220 (2005).

Table 1: Outliers Removed from Dataset

Company Name	Year	Sedol	R&D Expense	Revenue	Net Income
BioFarm Bucurest	2003	B0RR188	24,084.9	1,270,354.0	286,177.4
May & Baker Nigeria	2007	6227591	74,323.1	36,011.4	1,943.6
May & Baker Nigeria	2008	6227591	37,220.3	42,055.2	3,231.2
DHG Pharmaceuticals	2010	B1L5527	4,536.4	10,956,620.0	2,052,690.0

Table 2: Data Points with Negative Revenues

Company Name	Year	Sedol	R&D Expense	Revenue	Net Income
Acorda Therapeutics	2004	2925844	26.4	(4.7)	(53.7)
Exact Sciences	2008	2719951	2.2	(0.9)	(10.5)
Achillion Pharma	2008	B17T9T8	22.8	(0.3)	(30.4)
Achillion Pharma	2009	B17T9T8	19.7	(0.3)	(27.7)

Figure 4 shows how North America has continued to be the leader in terms of the number of companies incorporated there, but its share has declined over the years as other regions grow and become prominent from 67% in 1999 to 44% in 2013. Asia has started to show a strong presence with a 932% growth since 1999 which amounts to a 16.8% compounded annual growth rate. However, Figure 5 shows that Western European companies are the largest in terms of market capitalization. The average size of North American companies started out high, at approximately $5.5 billion, but have since then trended downwards towards the mean. The worldwide pharmaceutical and biotech industry has grown in size, mostly due to the overall increase in the number of companies.

Figure 4: Number of BioPharma Companies per Region

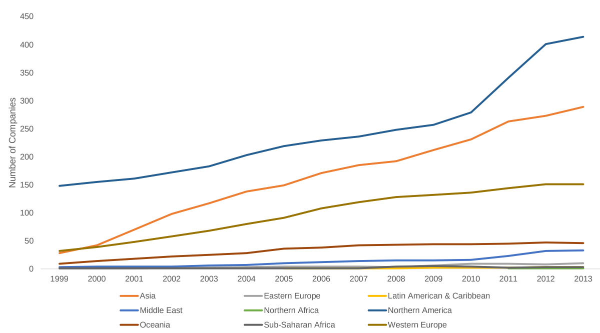
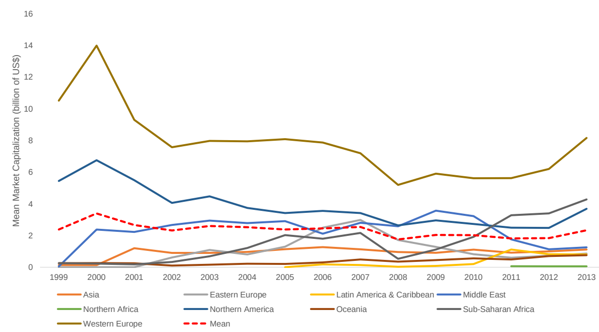


Figure 5: Total Market Capitalization of BioPharma Companies per Region



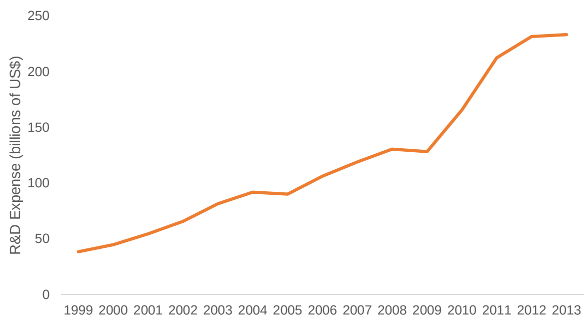
As shown in Figure 6, there has been a steady increase in total R&D expense with a tapering off beginning in 2011. The decline in in R&D expenses after 2011 appears to coincide with the decline in net income and revenues for the industry. The average profit margins for the industry have also been declining since 1999. There has been a decline of approximately 40% in margins from 1999 to 2013. Profit margins for the industry is at its highest (16.7%) in 1999 and at its lowest (8.4%) in 2008, corresponding to the world financial crisis. Margins appear to recover slightly to 10.0% in 2013. Next, R&D intensity is calculated as the ratio of R&D expense to revenues in a given year. There has been a slightly declining trend in R&D intensity. Given that the total R&D expense and sales have both been increasing for the industry as a whole, the declining trend of R&D productivity bolsters the idea that sales are growing faster than the R&D expense for companies.

Only FDA approvals for new molecular entities (NMEs) and new therapeutic biological products (BLAs) were considered. An NME is a drug that is unique in composition and does not have precedent compared to other drugs approved by the FDA. There are specific requirements for clinical trials in terms of efficacy and safety.[21] NMEs are the main source of value for the pharmaceutical and biotech industry, and arguably the society at large. This makes them a good measure of R&D outputs for pharmaceutical and biotech companies.[22]

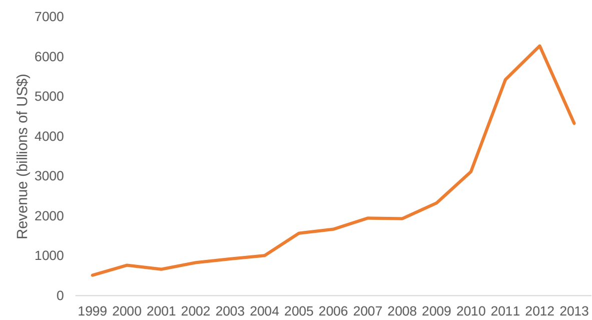
[21] Food & Drug Administration
[22] Pammolli, F., Magazzini, L., Riccaboni, M., The Productivity Crisis in Pharmaceutical R&D. *Nature Drug Discovery*. 10, 428-438 (2011).

Figure 6: Trends in Financials for the BioPharma Industry

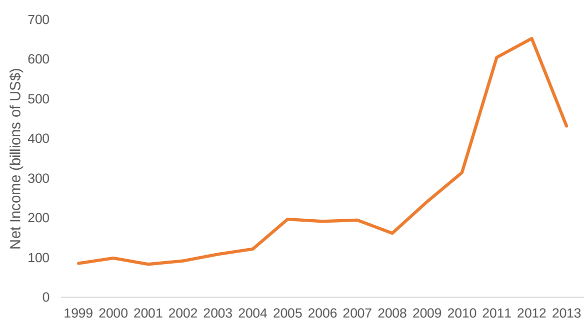
6a: Total R&D Expense



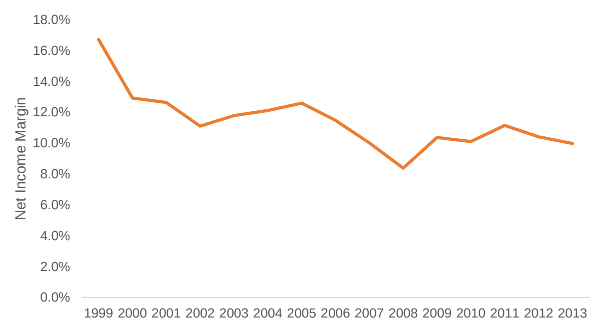
6b: Total Revenue



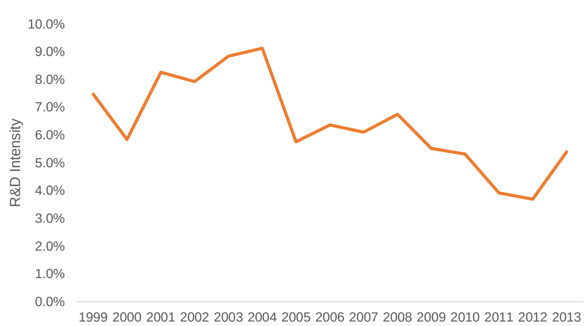
6c: Total Net Income



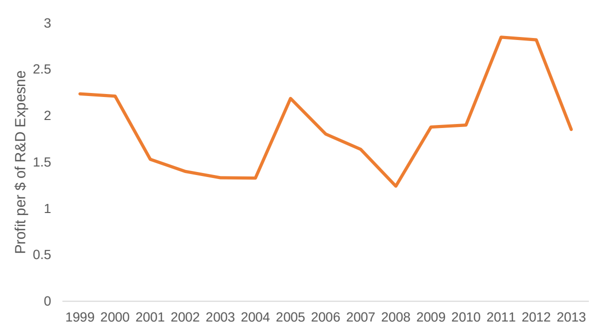
6d: Net Income Margin



6e: R&D Intensity

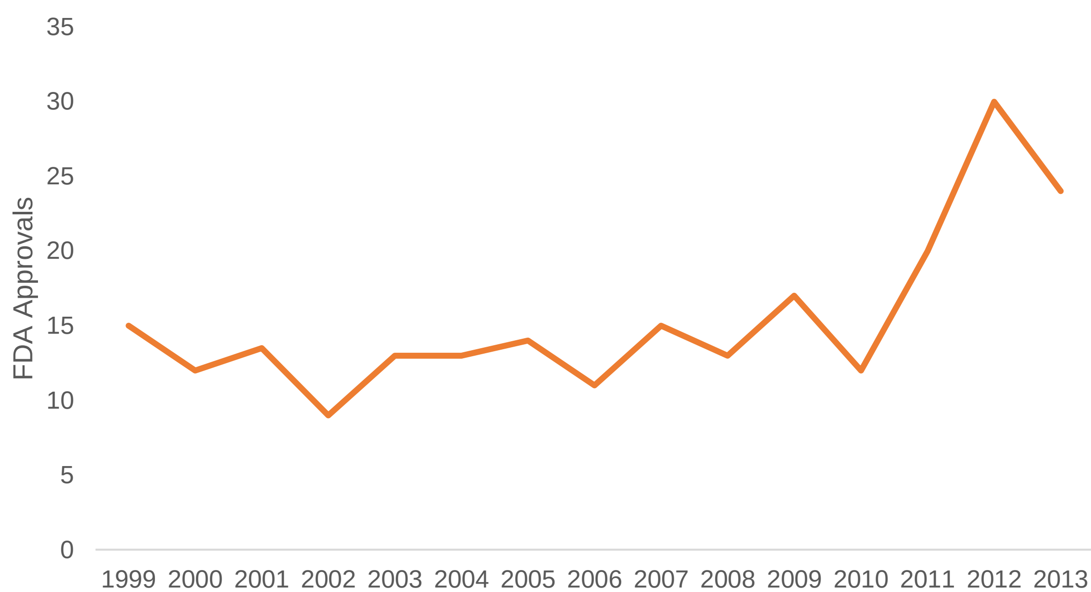


6f: Profit per $ of R&D Expense



The NME FDA approvals were assigned to their corresponding company and year in the dataset. Therefore, the data excludes NME approvals acquired by private companies as well as companies that do not fall under the broad industry categorization of pharmaceutical or biotech. Figure 7 shows that the trend in FDA approvals was fairly stable with a large spike in 2012. This corresponded to a very large increase in the NME applications filed as well.[23]

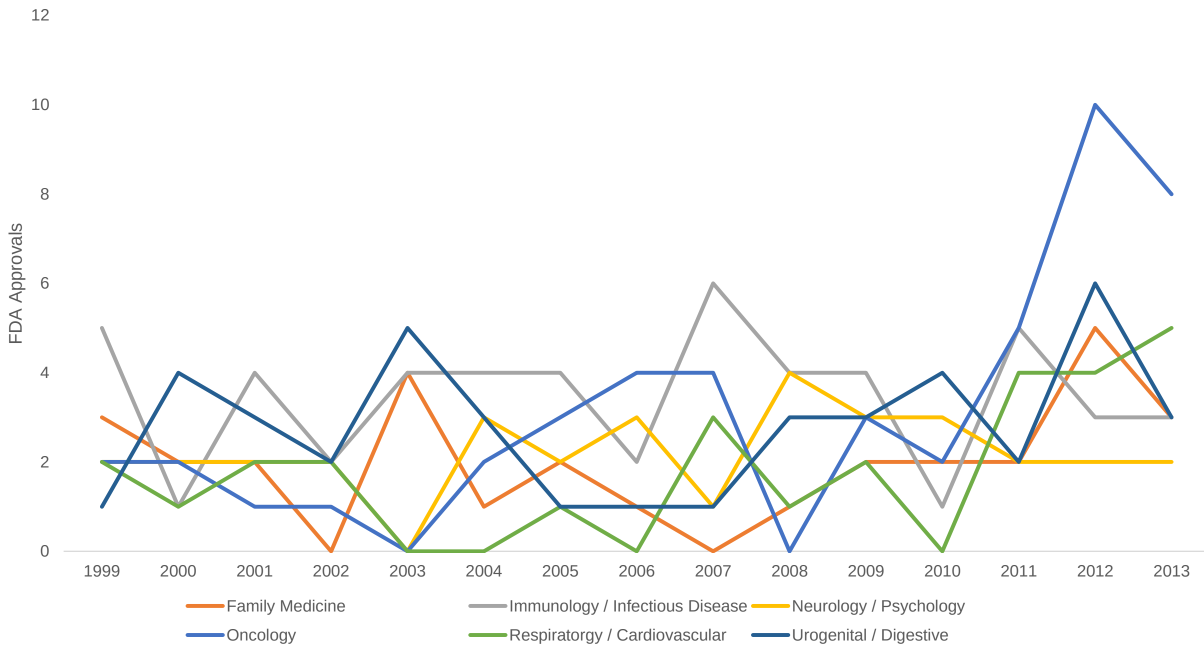
Figure 7: Number of NME FDA Approvals Awarded to Public BioPharma Companies



There has been a constant mix in the therapeutic areas which were in focus for the FDA approvals. No clear trend can be seen except the notable rise in FDA approvals focused on oncology drugs starting in 2011 (Figure 8).

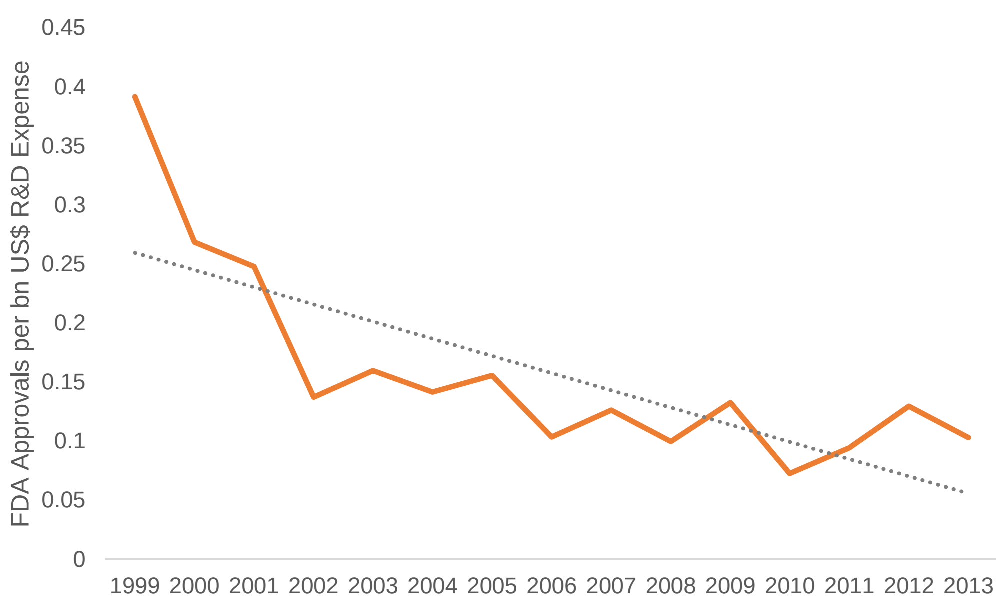
[23] Center for Drug Evaluation and Research, Novel New Drugs 2013 Summary. *US Food and Drug Administration*. (2014).

Figure 8: FDA NME Approval by Therapeutic Area



FDA approvals per R&D expense serves as a proxy for analyzing R&D productivity. Figure 9 shows the trend in FDA approvals per billion US$ spend in R&D expenditures. The trend seen is similar to the trend shown by Scannell, et. al. (Figure 2).

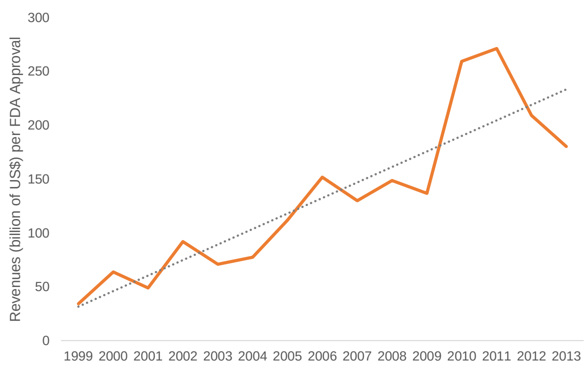
Figure 9: Trend in BioPharma R&D Productivity



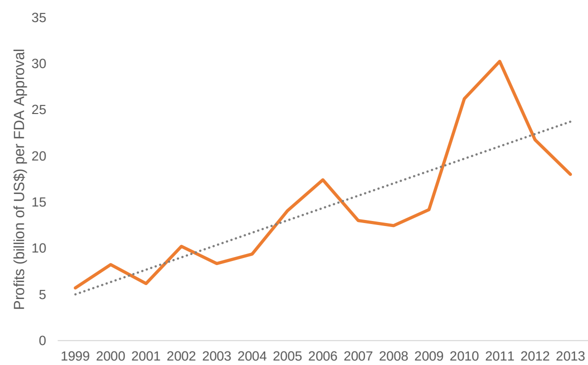
There are differences in the resulting numbers assigned to each year due to the disparities in datasets. Scannell, et. al. utilizes a dataset of 56 companies provided by Pharmaceutical Research and Manufacturers of America (Phrma) organization.[24] Even though it has become more expensive to create a new drug, the benefits of the FDA approvals have also increased. As shown in Figure 9, both the revenues and profits per FDA approval have been increasing with the maximum profitability in 2011.

Figure 9: Trend in the Benefits of FDA Approvals

9a: Revenues per FDA Approval



9b: Profits per FDA Approval



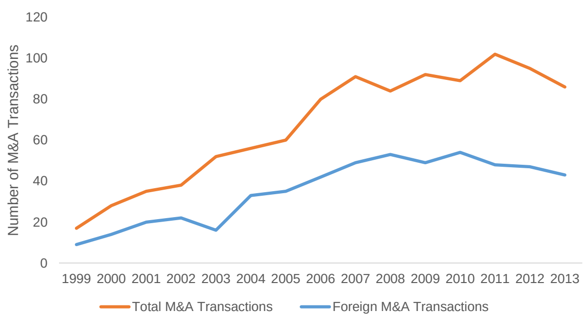
M&A transactions were obtained from SDC Platinum. The same company set was used to search for transactions that closed between the dates of January 1, 1999 and December 31, 2013. Only transactions which were or estimated to be at least over $1 million were included in the dataset. The acquirer was given credit for each of its transactions for each year. A total of 1,005 transactions were seen between 1999 and 2013. Out of these, 534 or 53.1% were foreign transactions which are defined as the target's location of incorporation being different from the

[24] Scannell, J.W., Blanckley, A., Boldon, H., Warrington, B. Diagnosing the decline in pharmaceutical R&D Efficiency. *Nature Drug Discovery*. 11, 192-200 (2012).

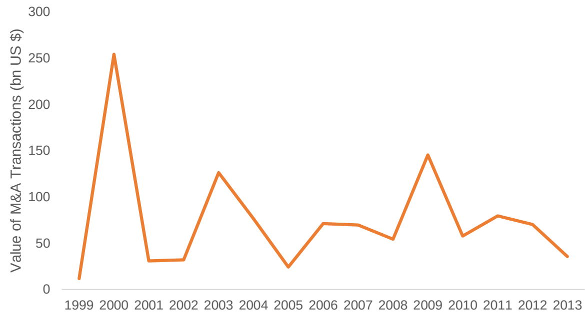
acquirer's location of incorporation. This has remained as the approximate % of foreign transactions.

Figure 10: Trends in M&A Transactions

10a: Total Number of M&A Transactions



10b: Value of M&A Transactions



As shown in Figure 10, both have growth since 1999 at similar rates. A large amount of consolidation occurred between 2008 and 2011. This might be attributed to the financial crisis and the overall difficulties companies were facing in finding capital funding and earning profits. However, the value of the transactions have greatly varied between years. Table 3 summarizes the variables and Table 4 shows the variable correlations.

Table 3: Summary of Dataset

Variable	Mean	Median	Min	Max	Std. Dev.
R&D Expense	213.3	8.7	(0.6)	15,930.3	1,027.0
Revenue	3,957.9	12.6	(4.7)	2,442,507.0	51,810.4
Net Income	426.0	(3.2)	(6,241.6)	269,788.7	6,026.8
Market Capitalization	3,602.7	110.4	0.0	290,215.8	18,945.8
FDA Approvals	0.0	0.0	0.0	4.0	0.2
# M&A Transactions	0.1	0.0	0.0	8.0	0.5
Value M&A Transactions	135.5	0.0	0.0	89,167.7	2,245.4
# Foreign M&A Transactions	0.1	0.0	0.0	7.0	0.3

Note: R&D expense, revenue, net income, and market capitalization are in millions of 2013 dollars

Table 4: Correlations between Variables in Dataset

	1	2	3	4	5	6	7	8
1. R&D Expense	1.0000							
2. Revenue	0.3948	1.0000						
3. Net Income	0.4367	0.9718	1.0000					
4. Market Capitalization	0.7938	0.0968	0.1584	1.0000				
5. FDA Approvals	0.4607	0.0540	0.0913	0.5705	1.0000			
6. # M&A Transactions	0.4321	0.0748	0.0953	0.4443	0.2898	1.0000		
7. Value M&A Transactions	0.2960	0.0295	0.0347	0.3521	0.1618	0.2484	1.0000	
8. # Foreign M&A Transactions	0.3076	0.0350	0.0523	0.3315	0.2327	0.8161	0.1768	1.0000

V. Regressions & Results

There are two types of analyses that need to be run. The first explores the relationship between M&A transactions and R&D expense. A set of regressions were run in order to determine how historical R&D expense impacts the probability of pursuing an M&A transaction. Four different types of regression analyses are used to look at the relationship since M&A approvals are count data – (1) OLS, (2) Tobit Model, (3) Logistic Model, and (4) Poisson Model. The equations for the OLS regressions run are as follows:

1. # of M&A Transactions$_t$ = $\alpha + \beta_1 \log(\text{R\&D Expense})_{t-1} + \beta_2(\text{Other Controls}) + \varepsilon$
2. # of M&A Transactions$_t$ = $\alpha + \beta_1 \log(\text{R\&D Expense})_{t-3} + \beta_2(\text{Other Controls}) + \varepsilon$
3. # of M&A Transactions$_t$ = $\alpha + \beta_1 \log(\text{R\&D Expense})_{t-5} + \beta_2(\text{Other Controls}) + \varepsilon$
4. # of M&A Transactions$_t$ = $\alpha + \beta_1 \sum_{t=1}^{3} \text{Log (R\&D Expense)}_{t-1} + \beta_2(\text{Other Controls}) + \varepsilon$
5. # of M&A Transactions$_t$ = $\alpha + \beta_1 \sum_{t=1}^{4} \text{Log (R\&D Expense)}_{t-1} + \beta_2(\text{Other Controls}) + \varepsilon$
6. # of M&A Transactions$_t$ = $\alpha + \beta_1 \sum_{t=1}^{5} \text{Log (R\&D Expense)}_{t-1} + \beta_2(\text{Other Controls}) + \varepsilon$

The other controls used include revenue, net income, market cap, year dummies, sub industry dummies, and region dummies. The results are shown in Table 5 with each number corresponding to the above regressions.

Table 5: Regression Output (R&D Expense Impact on M&A)

Regression 1:

	OLS				Tobit				Logistic				Poisson			
M&A Transactions	1		2		1		2		1		2		1		2	
Log(R&D)(t-1)	0.0896	***	-0.0074		0.6344	***	-0.2011	***	0.0334	***	-0.0133	***	1.5904	***	0.8078	***
	(0.0028)		(0.0057)		(0.0294)		(0.0489)		(0.0013)		(0.0030)		(0.0194)		(0.0272)	
Log(Revenues)			0.0380	***			0.3419	***			0.0196	***			1.4546	***
			(0.0042)				(0.0400)				(0.0025)				(0.0420)	
Log(Net Income)			0.3840	***			(0.0568)				-(0.0060)				0.8322	**
			(0.0347)				(0.2044)				(0.0122)				(0.0739)	
Log(Market Capitalization)			0.0490	***			0.4566	***			0.0277	***			1.3399	***
			(0.0047)				(0.0456)				(0.0027)				(0.0380)	
Adjusted R-Squared	0.1211		0.1971		0.1187		0.1905		0.1546		0.2492		0.2050		0.2950	
No. Observations	7,336				7,336				7,336				7,336			

Regression 2:

	OLS				Tobit				Logistic				Poisson			
M&A Transactions	1		2		1		2		1		2		1		2	
Log(R&D)(t-3)	0.1026	***	0.0103		0.6545	***	-0.1023	***	0.0382	***	-0.0083	***	1.5984	***	0.8734	***
	(0.0035)		(0.0066)		(0.0328)		(0.0539)		(0.0016)		(0.0034)		(0.0214)		(0.0318)	
Log(Revenues)			0.0431	***			0.3556	***			0.0207	***			1.4848	***
			(0.0051)				(0.0453)				(0.0030)				(0.0461)	
Log(Net Income)			0.3931	***			(0.0187)				-(0.0073)				0.7774	**
			(0.0405)				(0.2203)				(0.0137)				(0.0710)	
Log(Market Capitalization)			0.0345	***			0.3530	***			0.0236	***			1.2221	***
			(0.0058)				(0.0531)				(0.0034)				(0.0396)	
Adjusted R-Squared	0.1350		0.2082		0.1232		0.1906		0.1641		0.2518		0.2126		0.2999	
No. Observations	5,436				5,436				5,436				5,436			

Regression 3:

	OLS				Tobit				Logistic				Poisson			
M&A Transactions	1		2		1		2		1		2		1		2	
Log(R&D)(t-5)	0.1165	***	0.0200		0.6740	***	-0.0630	***	0.0418	***	-0.0072	***	1.6232	***	0.9229	***
	(0.0043)		(0.0078)		(0.0371)		(0.0584)		(0.0020)		(0.0039)		(0.0243)		(0.0368)	
Log(Revenues)			0.0406	***			0.3124	***			0.0189	***			1.4661	***
			(0.0063)				(0.0519)				(0.0036)				(0.0540)	
Log(Net Income)			0.4918	***			(0.1676)				(0.0059)				0.7171	**
			(0.0478)				(0.2474)				(0.0160)				(0.0859)	
Log(Market Capitalization)			0.0333	***			0.3631	***			0.0255	***			1.1999	***
			(0.0072)				(0.0625)				(0.0043)				(0.0476)	
Adjusted R-Squared	0.1526		0.2401		0.1280		0.2043		0.1710		0.2694		0.2300		0.3228	
No. Observations	3,996				3,996				3,996				3,996			

Regression 4:

M&A Transactions	OLS 1		OLS 2		Tobit 1		Tobit 2		Logistic 1		Logistic 2		Poisson 1		Poisson 2	
Log(R&D)(past 3 years)	0.0348	***	0.0027		0.2216	***	-0.0399	**	0.0128	***	-0.0031	**	1.1712	***	0.9491	***
	(0.0012)		(0.0024)		(0.0110)		(0.0192)		(0.0005)		(0.0012)		(0.0052)		(0.0124)	
Log(Revenues)			0.0436	***			0.3600	***			0.0210	***			1.4998	***
			(0.0051)				(0.0457)				(0.0030)				(0.0480)	
Log(Net Income)			0.3966	***			(0.0352)				-(0.0063)				0.7845	***
			(0.0406)				(0.2211)				(0.0137)				(0.0723)	
Log(Market Capitalization)			0.0352	***			0.3631	***			0.0242	***			1.2334	***
			(0.0060)				(0.0545)				(0.0034)				(0.0408)	
Adjusted R-Squared	0.1391		0.2080		0.1281		0.1907		0.1699		0.2520		0.2179		0.3003	
No. Observations	5,436				5,436				5,436				5,436			

Regression 5:

M&A Transactions	OLS 1		OLS 2		Tobit 1		Tobit 2		Logistic 1		Logistic 2		Poisson 1		Poisson 2	
Log(R&D)(past 4 years)	0.0281	***	0.0033	*	0.1681	***	-0.0203		0.0103	***	-0.0018	*	1.1282	***	0.9724	***
	(0.0010)		(0.0020)		(0.0086)		(0.0154)		(0.0004)		(0.0010)		(0.0040)		(0.0104)	
Log(Revenues)			0.0413	***			0.3394	***			0.0211	***			1.4738	***
			(0.0057)				(0.0484)				(0.0033)				(0.0508)	
Log(Net Income)			0.4904	***			(0.1394)				-(0.0014)				0.7501	**
			(0.0450)				(0.2390)				(0.0153)				(0.0857)	
Log(Market Capitalization)			0.0336	***			0.3371	***			0.0230	***			1.2101	***
			(0.0068)				(0.0591)				(0.0040)				(0.0451)	
Adjusted R-Squared	0.1516		0.2265		0.1328		0.1942		0.1762		0.2565		0.2285		0.3058	
No. Observations	4,687				4,687				4,687				4,687			

Regression 6:

M&A Transactions	OLS 1		OLS 2		Tobit 1		Tobit 2		Logistic 1		Logistic 2		Poisson 1		Poisson 2	
Log(R&D)(past 5 years)	0.0240	***	0.0037	**	0.1390	***	-0.0139		0.0085	***	-0.0014		1.1041	***	0.9814	**
	(0.0009)		(0.0017)		(0.0074)		(0.0132)		(0.0004)		(0.0009)		(0.0033)		(0.0090)	
Log(Revenues)			0.0407	***			0.3150	***			0.0190	***			1.4756	***
			(0.0063)				(0.0526)				(0.0037)				(0.0560)	
Log(Net Income)			0.4958	***			(0.1708)				(0.0056)				0.7220	***
			(0.0480)				(0.2489)				(0.0162)				(0.0874)	
Log(Market Capitalization)			0.0333	***			0.3673	***			0.0255	***			1.2071	***
			(0.0075)				(0.0650)				(0.0044)				(0.0497)	
Adjusted R-Squared	0.1632		0.2397		0.1403		0.2043		0.1865		0.2691		0.2435		0.3228	
No. Observations	3,996				3,996				3,996				3,996			

Standard Errors are reported in parentheses
*** indicates significance at the 99% level
** indicates significance at the 95% level
* indicates significance at the 90% level

Though there was no significant correlation between lagged R&D expense and the number of M&A transactions in the OLS regressions, there was consistently a significant negative correlation between the two variables in the other types of regressions. Also, there was always a significant negative relationship between aggregate R&D expense greater than 4 years and the number of M&A transaction. This suggests that as the amount of internal R&D increases, the probability of the firm pursuing an M&A transaction declines. This corresponds with the idea that firms will either focus on internal R&D investment or try and replace it through acquiring R&D capabilities from other firms.

A second view is to understand how M&A transactions impact future R&D expense. The following are the OLS regression equations for this analysis.

1. $\text{Log(R\&D Expense)}_t = \alpha + \beta_1\text{(Number of M\&A Transactions)}_{t-1} + \beta_2\text{(Other Controls)} + \varepsilon$
2. $\text{Log(R\&D Expense)}_t = \alpha + \beta_1\text{(Number of M\&A Transactions)}_{t-3} + \beta_2\text{(Other Controls)} + \varepsilon$
3. $\text{Log(R\&D Expense)}_t = \alpha + \beta_1\text{(Number of M\&A Transactions)}_{t-5} + \beta_2\text{(Other Controls)} + \varepsilon$
4. $\sum_{t=1}^{3} \text{Log (R\&D Expense)}_t = \alpha + \beta_1\text{(Number of M\&A Transactions)}_{t-4} + \beta_2\text{(Other Controls)} + \varepsilon$
5. $\sum_{t=1}^{4} \text{Log (R\&D Expense)}_t = \alpha + \beta_1\text{(Number of M\&A Transactions)}_{t-4} + \beta_2\text{(Other Controls)} + \varepsilon$
6. $\sum_{t=1}^{5} \text{Log (R\&D Expense)}_t = \alpha + \beta_1\text{(Number of M\&A Transactions)}_{t-4} + \beta_2\text{(Other Controls)} + \varepsilon$

The other controls used include revenue, net income, market cap, year dummies, sub industry dummies, and region dummies. The results are shown in Table 6 with each number corresponding to the above regressions.

Table 6: Regression Output (M&A Impact on R&D Expense)

Regression 1:

R&D Expense	1	2
M&A Transactions(t-1)	1.4081 ***	-0.0399
	(0.0436)	(0.0253)
Log(Revenues)(t-1)		0.2731 ***
		(0.0081)
Log(Net Income)(t-1)		1.1220 ***
		(0.0729)
Log(Market Capitalization)(t-1)		0.4988 ***
		(0.0087)
Adjusted R-Squared	0.1245	0.7784
No. Observations	7,336	

Regression 2:

R&D Expense	1	2
M&A Transactions(t-3)	1.4224 ***	0.0237
	(0.0494)	(0.3660)
Log(Revenues)(t-1)		0.1816 ***
		(0.0088)
Log(Net Income)(t-1)		1.2662 ***
		(0.0764)
Log(Market Capitalization)(t-1)		1.2662 ***
		(0.0093)
Adjusted R-Squared	0.1320	0.8098
No. Observations	5,436	

Regression 3:

R&D Expense	1	2
M&A Transactions(t-5)	1.6326 ***	0.0080
	(0.0620)	(0.0314)
Log(Revenues)(t-1)		0.1434 ***
		(0.0102)
Log(Net Income)(t-1)		1.3798 ***
		(0.0809)
Log(Market Capitalization)(t-1)		0.6077 ***
		(0.0107)
Adjusted R-Squared	0.1476	0.8313
No. Observations	3,996	

Regression 4:

R&D Expense	1	2
M&A Transactions(t-3)	4.2258 ***	0.1066
	(0.1452)	(0.0782)
Log(Revenues)(t-1)		0.5910 ***
		(0.0264)
Log(Net Income)(t-1)		3.8106 ***
		(0.2281)
Log(Market Capitalization)(t-1)		1.6000 ***
		(0.0279)
Adjusted R-Squared	0.1347	0.8038
No. Observations	5,436	

Regression 5:

R&D Expense	1	2
M&A Transactions(t-4)	5.7962 ***	0.2533 **
	(0.2082)	(0.1107)
Log(Revenues)(t-1)		0.6996 ***
		(0.0379)
Log(Net Income)(t-1)		5.0936 ***
		(0.3056)
Log(Market Capitalization)(t-1)		2.1568 ***
		(0.0399)
Adjusted R-Squared	0.1417	0.8096
No. Observations	4,687	

Regression 6:

R&D Expense	1	2
M&A Transactions(t-5)	8.0789 ***	0.3229 **
	(0.2981)	(0.1599)
Log(Revenues)(t-1)		0.8290 ***
		(0.0520)
Log(Net Income)(t-1)		7.0577 ***
		(0.4123)
Log(Market Capitalization)(t-1)		2.6648 ***
		(0.0547)
Adjusted R-Squared	0.1551	0.8120
No. Observations	3,996	

Standard Errors are reported in parentheses
*** indicates significance at the 99% level
** indicates significance at the 95% level

With the lagged regressions, there is no significant impact of M&A transactions on the R&D expense in the future. However, revenues, net income, and market capitalization all have significant positive relationships with future R&D expense. The range of M&A transaction lags is utilized in order to take into account the delay in effect a transaction can have on the proforma company. As Hitt, et. al. (1991) showed in their paper, the reasoning behind the transaction and the overall structures and specialties of both firms impacts the final level of R&D expense.[25] There is a diverse group of types of M&A transactions that have been included in the sample, as transaction motivation was not a filter. R&D can increase or decrease depending on the specific situation. However, the effect of an M&A transaction has a significant impact on the 4 year and 5 year cumulative R&D expense. This suggests that M&A transactions have a prolonged effect on R&D expense of the acquiring company. Rather than there being just one year where there is a significant impact, it is seen in a more general trend which becomes more visible four years after the transaction

Second, there is an analysis that actually looks at the impact past M&A transactions have on R&D productivity today. FDA approvals was used as a proxy for R&D productivity. The regressions look at the direct impact of each of the variables on FDA approvals. Similar to the first regression analysis, the relationship is looked at with different time lags and cumulative effects. Four different types of regression analyses are used to look at the relationship since FDA approvals are count data – (1) OLS, (2) Tobit Model, (3) Logistic Model, and (4) Poisson Model.

[25] Hitt, M.A, Hoskisson, R.E., Ireland, R.D., Harrison, J.S., Effects of Acquisitions on R&D Inputs and Outputs. *Academy of Management Journal*. 34 (3), 693-706 (1991).

The OLS regression equations for the direct relationship analysis is as follows:

1. $\text{FDA Approval}_t = \alpha + \beta_1(\text{Number of M\&A Transactions})_{t-1} + \beta_2\log(\text{R\&D Expense})_{t-1} + \beta_3(\text{Other Controls}) + \varepsilon$
2. $\text{FDA Approval}_t = \alpha + \beta_1(\text{Number of M\&A Transactions})_{t-4} + \beta_2\log(\text{R\&D Expense})_{t-4} + \beta_3(\text{Other Controls}) + \varepsilon$
3. $\text{FDA Approval}_t = \alpha + \beta_1(\text{Number of M\&A Transactions})_{t-8} + \beta_2\log(\text{R\&D Expense})_{t-8} + \beta_3(\text{Other Controls}) + \varepsilon$
4. $\text{FDA Approval}_t = \alpha + \beta_1\sum_{t=1}^{4} \text{Number of M\&A Transactions} + \beta_2\sum_{t=1}^{4} \text{Log (R\&D Expense)} + \beta_3(\text{Other Controls}) + \varepsilon$
5. $\text{FDA Approval}_t = \alpha + \beta_1\sum_{t=1}^{5} \text{Number of M\&A Transactions} + \beta_2\sum_{t=1}^{5} \text{Log (R\&D Expense)} + \beta_3(\text{Other Controls}) + \varepsilon$
6. $\text{FDA Approval}_t = \alpha + \beta_1\sum_{t=1}^{3} \text{Number of M\&A Transactions} + \beta_2\sum_{t=1}^{3} \text{Log (R\&D Expense)} + \beta_3(\text{Other Controls}) + \varepsilon$

The other controls are the same as the first analysis. The results are shown in Table 7 with each number corresponding to the above regressions.

Table 7: Regression Output (M&A Impact on FDA Approvals)

Regression 1:

	OLS			Tobit			Logistic			Poisson		
FDA Approvals	1	2	3	1	2	3	1	2	3	1	2	3
M&A Transactions(t-1)	0.1359 ***	0.0996 ***	0.0800 ***	1.3793 ***	0.3043 ***	0.1916 **	0.0215 ***	0.0040 ***	0.0023	2.0749 ***	1.1733 ***	1.1145 **
	(0.0047)	(0.0049)	(0.0053)	(0.1195)	(0.0838)	(0.0846)	(0.0018)	(0.0014)	(0.0017)	(0.0598)	(0.0555)	(0.0603)
Log(R&D)(t-1)		0.0256 ***	0.0048 *		0.6918 ***	0.2228 **		0.0131 ***	0.0067 ***		2.0724 ***	1.3353 **
		(0.0012)	(0.0025)		(0.0570)	(0.0965)		(0.0009)	(0.0025)		(0.0731)	(0.1511)
Log(Revenues)(t-1)			-0.0026			-0.1532 **			-0.0038 **			0.8395 **
			(0.0018)			(0.0675)			(0.0016)			(0.0664)
Log(Net Income)(t-1)			0.2190 ***			0.1724			-0.0013			0.9332
			(0.0154)			(0.2844)			(0.0060)			(0.1729)
Log(Market Capitalization)(t-1)			0.0183 ***			0.6114 ***			0.0128 ***			1.8756 ***
			(0.0022)			(0.1042)			(0.0025)			(0.2130)
Adjusted R-Squared	0.1035	0.1535	0.1927	0.1141	0.3067	0.3552	0.1276	0.3748	0.4235	0.1328	0.4027	0.4466
No. Observations	7,336			7,336			7,336			7,336		

Regression 2:

	OLS			Tobit			Logistic			Poisson		
FDA Approvals	1	2	3	1	2	3	1	2	3	1	2	3
M&A Transactions(t-3)	0.1377 ***	0.0933 ***	0.0723 ***	1.2653 ***	0.1885 **	0.1427	0.0252 ***	0.0030 *	0.0025	1.9728 ***	1.0658	1.0419
	(0.0056)	(0.0058)	(0.0060)	(0.1209)	(0.0847)	(0.0871)	(0.0024)	(0.0018)	(0.0021)	(0.0624)	(0.0569)	(0.0601)
Log(R&D)(t-3)		0.0316 ***	0.0099 ***		0.7033 ***	0.3102 ***		0.0159 ***	0.0090 ***		2.1400 ***	1.5095 ***
		(0.0015)	(0.0028)		(0.0596)	(0.0971)		(0.0011)	(0.0028)		(0.0826)	(0.1778)
Log(Revenues)(t-1)			-0.0031			-0.1561 **			-0.0043 **			0.8178 **
			(0.0021)			(0.0704)			(0.0020)			(0.0704)
Log(Net Income)(t-1)			0.2341 ***			-0.0551			-0.0065			0.7628
			(0.0180)			(0.2980)			(0.0073)			(0.1535)
Log(Market Capitalization)(t-1)			0.0177 ***			0.5559 ***			0.0138 ***			1.8191 ***
			(0.0025)			(0.1071)			(0.0030)			(0.2255)
Adjusted R-Squared	0.1006	0.1665	0.2028	0.1022	0.3161	0.1350	0.1218	0.3851	0.4216	0.1169	0.4099	0.4442
No. Observations	5,436			5,436			5,436			5,436		

Regression 3:

FDA Approvals	OLS 1	OLS 2	OLS 3	Tobit 1	Tobit 2	Tobit 3	Logistic 1	Logistic 2	Logistic 3	Poisson 1	Poisson 2	Poisson 3
M&A Transactions(t-5)	0.1817 ***	0.1290 ***	0.1061 ***	1.4431 ***	0.2402 **	0.1955 *	0.0326 ***	0.0033	0.0030	2.5008 ***	1.1000	1.0930
	(0.0074)	(0.0078)	(0.0080)	(0.1443)	(0.1029)	(0.1029)	(0.0032)	(0.0024)	(0.0028)	(0.1083)	(0.0690)	(0.0731)
Log(R&D)(t-5)		0.0327 ***	0.0096 ***		0.6772 ***	0.1837 *		0.0178 ***	0.0067 **		2.0862 ***	1.2987 **
		(0.0019)	(0.0034)		(0.0643)	(0.0969)		(0.0014)	(0.0031)		(0.0889)	(0.1489)
Log(Revenues)(t-1)			-0.0045 *			-0.1318 *			-0.0041 *			0.8424 *
			(0.0027)			(0.0785)			(0.0025)			(0.0819)
Log(Net Income)(t-1)			0.2418 ***			-(0.0183)			-0.0120			0.6663
			(0.0213)			(0.3709)			(0.0114)			(0.2179)
Log(Market Capitalization)(t-1)			0.0182 ***			0.6270 ***			0.0182 ***			2.0189 ***
			(0.0031)			(0.1221)			(0.0038)			(0.2848)
Adjusted R-Squared	0.1311	0.1894	0.2228	0.1145	0.3008	0.3449	0.1352	0.3695	0.4085	0.1584	0.4028	0.4388
No. Observations	3,996			3,996			3,996			3,996		

Regression 4:

FDA Approvals	OLS 1	OLS 2	OLS 3	Tobit 1	Tobit 2	Tobit 3	Logistic 1	Logistic 2	Logistic 3	Poisson 1	Poisson 2	Poisson 3
M&A Transactions(past 3 years)	0.0687 ***	0.0509 ***	0.0427 ***	0.5675 ***	0.1156 ***	0.0984 **	0.0113 ***	0.0019 **	0.0017 *	1.4052 ***	1.0528 **	1.0418
	(0.0022)	(0.0024)	(0.0026)	(0.0481)	(0.0362)	(0.0396)	(0.0009)	(0.0008)	(0.0010)	(0.0190)	(0.0247)	(0.0277)
Log(R&D)(past 3 years)		0.0084 ***	0.0031 ***		0.2189 ***	0.1073 ***		0.0050 ***	0.0034 ***		1.2787 ***	1.1668 ***
		(0.0005)	(0.0010)		(0.0199)	(0.0350)		(0.0004)	(0.0010)		(0.0179)	(0.0514)
Log(Revenues)(t-1)			-0.0052 **			-0.1578 **			-0.0044 **			0.8149 **
			(0.0021)			(0.0695)			(0.0019)			(0.0697)
Log(Net Income)(t-1)			0.2043 ***			-0.1102			-0.0072			0.7588
			(0.0181)			(0.2968)			(0.0074)			(0.1466)
Log(Market Capitalization)(t-1)			0.0151 ***			0.5116 ***			0.0122 ***			1.7070 ***
			(0.0026)			(0.1094)			(0.0031)			(0.2208)
Adjusted R-Squared	0.1576	0.1957	0.2204	0.1558	0.3220	0.3574	0.1806	0.3913	0.4234	0.1807	0.4150	0.4455
No. Observations	5,436			5,436			5,436			5,436		

Regression 5:

	OLS			Tobit			Logistic			Poisson		
FDA Approvals	1	2	3	1	2	3	1	2	3	1	2	3
M&A Transactions(past 4 years)	0.0602 ***	0.0467 ***	0.0421 ***	0.4376 ***	0.1037 ***	0.1060 ***	0.0096 ***	0.0019 ***	0.0022 **	1.3151 ***	1.0542 ***	1.0568 **
	(0.0018)	(0.0020)	(0.0022)	(0.0371)	(0.0292)	(0.0327)	(0.0008)	(0.0007)	(0.0009)	(0.0142)	(0.0203)	(0.0234)
Log(R&D)(past 4 years)		0.0059 ***	0.0026 ***		0.1556 ***	0.0720 ***		0.0039 ***	0.0024 ***		1.1925 ***	1.1185 ***
		(0.0004)	(0.0008)		(0.0152)	(0.0265)		(0.0003)	(0.0008)		(0.0132)	(0.0377)
Log(Revenues)(t-1)			-0.0073 ***			-0.1565 **			-0.0046 **			0.8233 **
			(0.0024)			(0.0713)			(0.0021)			(0.0728)
Log(Net Income)(t-1)			0.1691 ***			-0.2167			-0.0097			0.6970 *
			(0.0191)			(0.3109)			(0.0083)			(0.1364)
Log(Market Capitalization)(t-1)			0.0148 ***			0.5035 ***			0.0130 ***			1.6538 ***
			(0.0029)			(0.1137)			(0.0034)			(0.2242)
Adjusted R-Squared	0.1911	0.2207	0.2382	0.1708	0.3166	0.3506	0.1984	0.3858	0.4152	0.2050	0.4114	0.4390
No. Observations	4,687			4,687			4,687			4,687		

Regression 6:

	OLS			Tobit			Logistic			Poisson		
FDA Approvals	1	2	3	1	2	3	1	2	3	1	2	3
M&A Transactions(past 5 years)	0.0547 ***	0.0443 ***	0.0405 **	0.3703 ***	0.1055 ***	0.1096 **	0.0085 ***	0.0020 ***	0.0025 **	1.2798 ***	1.0571 ***	1.0633 ***
	(0.0016)	(0.0019)	(0.0021)	(0.0320)	(0.0259)	(0.0301)	(0.0007)	(0.0006)	(0.0008)	(0.0127)	(0.0184)	(0.0220)
Log(R&D)(past 5 years)		0.0042 ***	0.0016 **		0.1174 ***	0.0488 **		0.0031 ***	0.0019 **		1.1465 ***	1.0832 ***
		(0.0004)	(0.0008)		(0.0126)	(0.0221)		(0.0003)	(0.0007)		(0.0111)	(0.0308)
Log(Revenues)(t-1)			-0.0094 ***			-0.1469 *			-0.0048 **			0.8243 **
			(0.0026)			(0.0767)			(0.0024)			(0.0797)
Log(Net Income)(t-1)			0.1824 ***			-0.4029			-0.0223 *			0.4861 **
			(0.0213)			(0.4137)			(0.0120)			(0.1614)
Log(Market Capitalization)(t-1)			0.0152 ***			0.5293 ***			0.0147 ***			1.7818
			(0.0033)			(0.1247)			(0.0040)			(0.2708)
Adjusted R-Squared	0.2217	0.2429	0.2602	0.1938	0.3186	0.3529	0.2242	0.3885	0.4187	0.2388	0.4172	0.4462
No. Observations	3,996			3,996			3,996			3,996		

Standard Errors are reported in parentheses

*** indicates significance at the 99% level ** indicates significance at the 95% level * indicates significance at the 90% level

Almost all the time lags and aggregation of variable regressions show a statistically significant, positive relationship between M&A transactions and FDA approvals, with the exception of the logistic regression with only a one year lag and poisson regression which looks at the three year cumulative M&A and R&D expense. In this case, the reason for looking at large time lags between the M&A transaction and FDA approval and the cumulative impact of M&A transactions and R&D expense is that FDA approvals require a long process of development. The average time it takes to go through the entire drug development process is between 11 and 14 years.[26] A target company is usually in the middle of drug development and therefore, there is still additional process required before reaching the level of FDA approval. The two regressions with the strongest results are the cumulative year analysis over four years and five years.

Despite the significance of the regression analyses, there are some limitations. M&A activity may be driving R&D productivity, shown by FDA approvals, or R&D productivity can be causing the M&A transactions. The regressions which specify and estimate current R&D productivity as a function of M&A transactions three and five years prior alleviate this concern somewhat, but only imperfectly. Omitted variables, such as firm quality, may not be adequately captured by variables indicating past revenues and profitability, and may be driving both M&A and R&D productivity. Hence, the number of M&A transactions is an endogenous variable, with potential correlation between the variable and the error term. Therefore, we emphasize that the coefficients cannot be interpreted as causal. However, the coefficients for # of M&A transactions and R&D expense are positive and statistically significant. This can be interpreted as there being a positive relationship between these variables and FDA approvals.

[26] FDA Review

VI. Conclusion & Future Work

These results show that M&A transactions have a positive influence on R&D productivity for biopharma companies. This suggests that the number of M&A transactions possibly enhances a very important factor for determining the future value of a biopharma firm, R&D productivity. Still, this relationship between the direction of R&D productivity and the number of M&A transactions needs to be analyzed. Transaction size, the life cycle stage of the target, or the motivations for specific mergers might be impacting R&D productivity and further analysis on this might give a more distinct pattern. For example, M&A transactions focused predominantly on tax-inversions might be influencing the overall outcome of the relationship between M&A transactions and R&D productivity.