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Innovation in the pharmaceutical industry: New estimates of R&D costs☆

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ABSTRACT

The research and development costs of 106 randomly selected new drugs were obtained from a survey of 10 pharmaceutical firms. These data were used to estimate the average pre-tax cost of new drug and biologics development. The costs of compounds abandoned during testing were linked to the costs of compounds that obtained marketing approval. The estimated average out-of-pocket cost per approved new compound is $1395 million (2013 dollars). Capitalizing out-of-pocket costs to the point of marketing approval at a real discount rate of 10.5% yields a total pre-approval cost estimate of $2588 million (2013 dollars). When compared to the results of the previous study in this series, total capitalized costs were shown to have increased at an annual rate of 8.5% above general price inflation. Adding an estimate of post-approval R&D costs increases the cost estimate to $2870 million (2013 dollars).

1. Introduction

We provide an updated assessment of the value of the resources expended by industry to discover and develop new drugs and biologics, and the extent to which these private sector costs have changed over time. The costs required to develop these new products clearly play a role in the incentives to invest in the innovative activities that can generate medical innovation. Our prior studies also have been used by other researchers, including government agencies, to analyze various policy questions (US Congressional Budget Office, 1998, 2006).

The full social costs of discovering and developing new compounds will include these private sector costs, but will also include government-funded and non-profit expenditures on basic and clinical research that can result in leads and targets which drug developers can explore. These additional costs can be substantial.[1] However, it is difficult to identify and measure non-private expenditures that can be linked to specific new therapies. Thus, we focus here on the private sector costs.

The methodological approach used in this paper follows that used for our previous studies, although we apply additional statistical tests to the data (Hansen, 1979; DiMasi et al., 1991, 1995a,b, 2003, 2004; DiMasi and Grabowski, 2007). Because the methodologies are consistent, we can confidently make comparisons of the results in this study to the estimates we found for the earlier studies, which covered earlier periods, to examine and illustrate trends

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[1] For example, for fiscal year 2013, the United States National Institutes of Health (NIH) spent nearly $30 billion on the activities that it funds (http://officeofbudget.od.nih.gov/pdfs/FY15/Approp%20%20History%20by%20IC%20through%20FY%202013.pdf).

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0167-6296/

in development costs. These studies used compound-level data on the cost and timing of development for a random sample of new drugs first investigated in humans and annual company pharmaceutical R&D expenditures obtained through surveys of a number pharmaceutical firms.

We analyze private sector R&D activities as long-term investments. The industrial R&D process is marked by substantial financial risks, with expenditures incurred for many development projects that fail to result in a marketed product. Thus, our approach explicitly links the costs of unsuccessful projects to those that are successful in obtaining marketing approval from regulatory authorities. In addition, the pharmaceutical R&D process is very lengthy, often lasting a decade or more (DiMasi et al., 2003). This makes it essential to model accurately how development expenses are spread over time.

Given our focus on resource costs and how they have changed over time, we develop estimates of the average pre-tax cost of new drug development and compare them to estimates covering prior periods. We corroborated the basic R&D cost results in this study by examining the representativeness of our sample firms and our study data, and by incorporating a number of independently derived results and data relating to the industry and the drug development process into analyses that provide rough comparators for at least components of our cost results. The details of those analyses are provided in our online supplement.

The remainder of this paper is organized as follows. We briefly discuss the literature on pharmaceutical industry R&D costs since our 2003 study in Section 2. Section 3 briefly outlines the standard paradigm for the drug development process. In Section 4 we describe the survey sample data and the population from which they were drawn, and briefly outline the methodology used to derive full R&D cost estimates from data on various elements of the drug development process. We present base case pre- and post-marketing approval R&D cost estimates in Section 5. Sensitivity analyses are presented in Section 6. We describe the representativeness of our data, various approaches to validating our results, and responses to various critiques in Section 7. Finally, we summarize our findings in Section 8.

2. Previous studies of the cost of pharmaceutical innovation

Much of the literature on the cost of pharmaceutical innovation dating back decades has already been described by the authors in their previous two studies (DiMasi et al., 1991, 2003). The interested reader can find references and discussions about the prior research in those studies. The earliest studies often involved a case study of a single drug (typically without accounting for the cost of failed projects) or they analyzed aggregate data. We will focus here on studies and reports that have emerged since DiMasi et al. (2003) that involve the use of new data for at least some parts of the R&D process. The basic elements of these analyses are shown in Table 1.

Adams and Brantner (2006, 2010) sought to assess the validity of the results in DiMasi et al. (2003) with some alternative data. Specifically, in their 2006 article, they used a commercial pipeline database to separately estimate clinical approval and phase attrition rates, as well as phase development times.[2] They found a similar overall cost estimate ($868 million versus $802 million in year 2000 dollars).[3] The authors followed that study with another study that featured clinical phase out-of-pocket cost estimates derived from regressions based on publicly available data on company R&D expenditures (Adams and Brantner, 2010). They found a somewhat higher overall cost estimate ($1.2 billion in year 2000 dollars).[4]

In a paper authored by two of the authors of this study (DiMasi and Grabowski, 2007), we provided a first look at the costs of developing biotech products (specifically, recombinant proteins and monoclonal antibodies). The methodological approach was the same as that used for our studies of traditional drug development. We used some data from DiMasi et al. (2003) combined with new data on the costs of a set of biotech compounds from a single large biopharmaceutical company. Biotech drugs were observed to have a higher average clinical success rate than small molecule drugs, but this was largely offset by other cost components. We found that the full capitalized cost per approved new compound was similar for traditional and biotech development ($1.3 billion for biotech and $1.2 billion for traditional development in year 2005 dollars), after adjustments to compare similar periods for R&D expenditures.

The other studies shown in Table 1 are discussed in detail in the online supplement. One important finding emerging from the survey of cost studies in Table 1 is that clinical success rates are substantially lower for the studies focused on more recent periods. This observed trend is consistent with other analyses of success probabilities (DiMasi et al., 2010; DiMasi et al., 2013; Hay et al., 2014; Paul et al., 2010) and our analysis below. Average R&D (inflation-adjusted) cost estimates are also higher for studies focused on more recent periods, suggesting a growth in real R&D costs. While suggestive, these studies are not strictly comparable to our earlier analyses of R&D costs given methodological differences and data omissions that are discussed in the online supplement (Appendix A).

3. The new drug development process

The new drug development process need not follow a fixed pattern, but a standard paradigm has evolved that fits the process well in general. We have described the process in some detail in previous studies, and the FDA's website contains a schematic explaining the usual set of steps along the way from test tube to new compound approval (http://www.fda.gov/Drugs/DevelopmentApprovalProcess/SmallBusinessAssistance/ucm053131.htm). Marketing approval applications for investigational compounds submitted to the FDA for review by manufacturers are referred to as new drug applications (NDAs) or biologic license applications (BLAs), depending on the type of product.

In basic form, the paradigm portrays new drug discovery and development as proceeding along a sequence of phases and activities (some of which often overlap). Basic and applied research initiate the process with discovery programs that result in the synthesis or isolation of compounds that are tested in assays and animal models in preclinical development. We do not have the level

[2] For mean out-of-pocket phase costs, they used the estimates in DiMasi et al. (2003).

[3] The Adams and Brantner (2006) study used records in the pipeline database that were reported to have entered some clinical testing phase from 1989 to 2002. Thus, they did not follow the same set of drugs through time. The data for the commercial pipeline databases are also thin prior to the mid-1990s. The DiMasi et al. (2003) study covered new drugs that had first entered clinical testing anywhere in the world from 1983 to 1994 and followed the same set of drugs through time.

[4] However, the authors interpreted their estimate as a marginal, as opposed to an average, drug cost. The concept, though, of marginal cost has an unclear meaning here. With high fixed costs and a development process that varies by drug, it is difficult to understand what marginal pharmaceutical R&D cost means in this context. It seems that the relevant marginal concept here is marginal profitability. The marginally profitable drug could have a very high or a very low cost. What's more, marginal profitability may only have meaning at the firm, not the industry, level. The cost of a marginally profitable drug in the pipeline of a firm may be high for one firm and low for another firm.

Table 1
Prior studies and analyses of pharmaceutical R&D costs (2003–2012).

Study	Study period	Clinical success rate	Real cost of capital	Inflation adjustment	Cost estimate
DiMasi et al. (2003)	First-in-humans, 1983–1994	21.5%	11.0%	2000 dollars	$802 million
Adams and Brantner (2006)	First-in-humans, 1989–2002	24.0%	11.0%	2000 dollars	$868 million
Adams and Brantner (2010)	Company R&D expenditures, 1985–2001	24.0%	11.0%	2000 dollars	$1.2 billion
DiMasi and Grabowski (2007)	First-in-humans, 1990–2003 (large molecule)	30.2% (large molecule)	11.5%	2005 dollars	$1.2 billion
Gilbert et al. (2003)	2000–2002 (launch)	8.0%	NA	2003 dollars	$1.7 billion
O'Hagan and Farkas (2009)	2009 (launch)	NA	NA	2009 dollars	$2.2 billion
Paul et al. (2010)	≈2007	11.7%	11.0%	2008 dollars	$1.8 billion
Mestre-Ferrandiz et al. (2012)	In clinical development, 1997–1999	10.7%	11.0%	2011 dollars	$1.5 billion

of granularity to disaggregate R&D expenditure data into discovery and preclinical development testing costs, so for the purposes of this study, as in prior studies, discovery and preclinical development costs are grouped and referred to as pre-human costs.[5]

Clinical (human) testing typically proceeds through three successive, sometimes overlapping phases. Historically, human testing has often been initiated first outside the United States (DiMasi, 2001). For any of these clinical phases, pharmaceutical companies may pursue development of their investigational compounds in multiple indications prior to and/or after the initial indication approval.

4. Data and methods

Ten multinational pharmaceutical firms of varying sizes provided data through a confidential survey of their new drug and biologics R&D costs.[6] Data were collected on clinical phase expenditures and development phase times for a randomly selected sample of the investigational drugs and biologics of the firms participating in the survey.[7] The sample was taken from a Tufts Center for the Study of Drug Development (CSDD) database of the investigational compounds of top 50 firms. Tufts CSDD gathered information on the investigational compounds in development and their development status from commercial pipeline intelligence databases (*IMS R&D Focus* and *Thomson Reuters Cortellis* database [formerly the *IDdb3* database]), published company pipelines, clinicaltrials.gov, and web searches. Cost and time data were also collected for expenditures on the kind of animal testing that often occurs concurrently with clinical trials.[8] The compounds chosen were self-originated in the following sense. Their development from synthesis up to initial regulatory marketing approval was conducted under the auspices of the surveyed firm. This inclusion criterion is broader than it might at first seem since it includes compounds of firms that were acquired or merged with the survey firm during development and drugs that originated with the survey firm and were co-developed (and for which full cost data were available).[9] Licensed-in and co-developed compounds without partner clinical cost data were excluded because non-survey firms would have conducted significant portions of the R&D.[10]

We also collected data from the cost survey participants on their aggregate annual pharmaceutical R&D expenditures for the period 1990–2010. The firms reported on total annual R&D expenditures broken down by expenditures on self-originated new drugs, biologics, diagnostics, and vaccines. Data were also provided on annual R&D expenditures for licensed-in or otherwise acquired new drugs, and on already-approved drugs. Annual expenditures on self-originated new drugs were further decomposed into expenditures during the pre-human and clinical periods.

The survey firms accounted for 35% of both top 50 firm pharmaceutical sales and pharmaceutical R&D expenditures. Of the 106 investigational compounds included in the project dataset, 87 are small molecule chemical entities (including three synthetic peptides), and 19 are large molecule biologics (10 monoclonal antibodies and nine recombinant proteins). For ease of exposition, we will refer to all compounds below as new drugs, unless otherwise indicated. Initial human testing anywhere in the world for these compounds occurred during the period 1995–2007. Development costs were obtained through 2013.

We selected a stratified random sample of investigational compounds.[11] Stratification was based on the status of testing as of the end of 2013. Reported costs were weighted to reflect the development status of compounds in the population relative to those in the cost survey sample, so that knowledge of the distribution of development status in the population from which the sample was drawn was needed. The population is composed of all investigational compounds in the Tufts CSDD investigational drug database that met study criteria: the compounds were self-originated and first tested in humans anywhere in the world from 1995 to 2007. We found 1442 investigational drugs that met these criteria. Of these compounds, 103 (7.1%) have been approved for marketing, 13 (0.9%) had NDAs or BLAs that were submitted and are still active, 11 (0.8%) had NDAs or BLAs submitted but abandoned, 576 (39.9%) were abandoned in phase I, 19 (1.3%) were still active in phase I, 492 (34.1%) were abandoned in phase II, 84 (5.8%) were still active in phase II, 78 (5.4%) were abandoned in phase III, and 66 (4.6%) were still active in phase III. For both the population and the cost survey sample, we estimated approval and discontinuation shares for the active compounds by phase so that the population and sample distributions consisted of shares of compounds that were approved or discontinued in phase I, phase II, phase III, or regulatory review. The

[5] We capture out-of-pocket discovery costs with our data, but the pre-synthesis discovery period is highly variable with no clear starting point. For our analyses we began our representative discovery and development timeline at the point of compound synthesis or isolation. Thus, our estimates of time costs are somewhat conservative.

[6] Using pharmaceutical sales in 2006 to measure firm size, 5 of the survey firms are top 10 companies, 7 are top 25 firms, and 3 are outside the top 25 (*Pharmaceutical Executive*, May 2007).

[7] A copy of the survey instrument can be found in our online supplement (Appendix G).

[8] Long-term teratogenicity and carcinogenicity testing may be conducted after the initiation of clinical trials, and is often concurrent with phase I and phase II testing.

[9] The criterion also does not preclude situations in which the firm sponsors trials that are conducted by or in collaboration with a government agency, an individual or group in academia, a non-profit institute, or another firm.

[10] Large and mid-sized pharmaceutical firms much more often license-in than license-out new drug candidates. Firms that license-in compounds for further development pay for the perceived value of the prior R&D typically through up-front fees, development and regulatory milestone payments, and royalty fees if the compound should be approved for marketing. For a breakdown of new drugs and biologics approved in the United States in the 2000s by business arrangements among firms initiated during clinical development, see DiMasi et al. (2014).

[11] To ease the burden of reporting and increase the likelihood that firms would respond, we limited the number of compounds to be reported on to a maximum of 15 for any firm (with fewer compounds for smaller firms).

cost survey sample was purposely weighted toward compounds that lasted longer in development to increase the amount of information on drugs that reached late-stage clinical testing. Weights, determined as described above, were then applied to the compounds in the cost dataset so that the results would reflect the development status distribution for the population from which the sample was drawn.

Some firms were not able to provide full phase cost data for every new drug sampled. For example, phase I cost data were available for 97 of the 106 new drugs in the dataset (92%). Of the 82 compounds in the dataset that had entered phase II, cost data were available for 78 (95%). For phase III, cost data were available for 42 of the 43 compounds that entered the phase (98%). However, we had cost data for at least one phase for each of the 106 drugs in the sample. In aggregate, we had cost data for all phases entered for 94 of the 106 compounds (89%).[12] In addition, five compounds were still active in a phase at the time that data were reported. For these drugs it is likely that there will be some additional future costs for the drug's most recent phase. Thus, for this reason our cost estimates are likely to be somewhat conservative. However, given the small number of drugs in this category and the fact that the impact would be on only one phase for each of these drugs, our overall cost estimates are not likely to be substantially affected.

The methodology that we use to estimate development costs is the same as the approach used in our earlier studies (Hansen, 1979; DiMasi et al., 1991, 2003). We refer the reader to the earlier studies and to our online supplement (Appendix A) for details. The methodology results in a full risk-adjusted cost per approved new compound that also takes into account time costs. That is, we link the cost of compound failures to the cost of the successes (investigational compounds that attain regulatory marketing approval), and we utilize a representative time profile along with an industry cost of capital to monetize the cost of the delay between when R&D expenditures are incurred and when returns to the successes can first be realized (date of marketing approval). We refer to the sum of out-of-pocket cost (actual cash outlays) and time cost per approved new compound as the capitalized cost per approved new compound. The full capitalized cost estimate is built through a number of estimates of various components of the drug development process. These individual component estimates are interesting as objects of analysis in their own right, and we provide estimates for those components.

5. Base case R&D cost estimates

5.1. Out-of-pocket clinical cost per investigational drug

To determine expected costs, we need estimates of the clinical development risk profile. We examined the dataset of 1442 self-originated compounds of top 50 pharmaceutical firms described above and estimated the phase transition probabilities shown in Fig. 1. The overall probability of clinical success (i.e., the likelihood that a drug that enters clinical testing will eventually be approved) was estimated to be 11.83%. This success rate is substantially lower than the rate of 21.50% estimated for the previous study, but consistent with several recent studies of clinical success rates.[13] Such an increase in overall risk will contribute greatly to an increase in costs per approved new drug, other things equal.

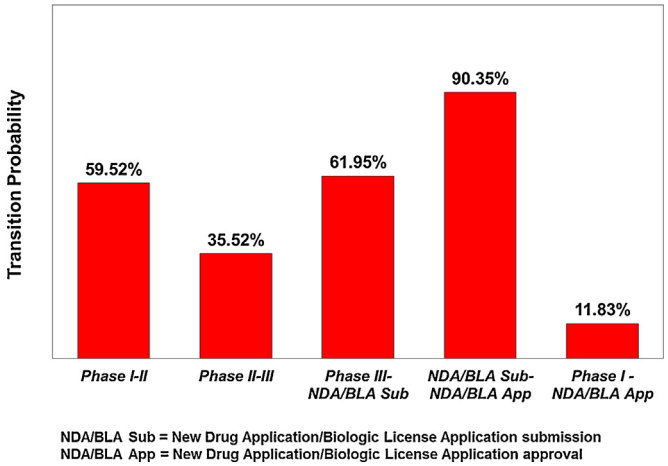

Fig. 1. Estimated phase transition probability and overall clinical approval success rates for self-originated new molecular entity (NME) and new therapeutically significant biologic entity (NBE) investigational compounds first tested in humans anywhere from 1995 to 2007.

As described above, we calculated weighted means, medians, standard deviations, and standard errors for clinical phase costs. Some of the firms could not separate out long-term animal testing costs during clinical development, and instead, included these costs in their phase cost estimates by year. To be consistent, therefore, for those compounds where animal costs were separately reported, we allocated those costs to the clinical phases according to when the animal testing costs were incurred. Thus, the clinical phase costs presented in Table 2 are inclusive of long-term animal testing costs.[14]

Weighted mean and median costs per investigational drug entering a phase[15] increase for later clinical phases, particularly for phase III (which typically includes a number of large-scale trials). In comparison to our previous study (DiMasi et al., 2003), both mean and median phase III cost are notably higher relative to the earlier phases. While the ratio of mean phase III cost to mean phase I cost was 5.7 for the previous study, it was 10.1 here. Similarly, the ratio of mean phase III to phase II cost was 3.7 for the earlier study, but was 4.4 for this study. Mean phase II cost was also higher relative to phase I cost in the current study compared to the previous one (2.3 times as high compared to 1.5 times as high).[16] Thus, while mean cost in real dollars for phase I increased 28% relative to the previous study,[17] phase I costs were notably lower relative to both phase II and phase III for the current study.

As we will see below, the differential in cost per approved new drug between the two studies will be much greater than cost per investigational drug because of the much lower overall clinical approval success rate. However, our results do show that the impact is mitigated to some degree by firms failing the drugs that they do abandon faster for the current study period. The distribution of clinical period failures for this study were 45.9% for phase I, 43.5% for phase II, and 10.6% for phase III/regulatory review. The

[12] Phase cost correlation results presented in the online supplement, together with an examination of relative phase costs for drugs that had some missing phase cost data, suggest that our phase cost averages (exclusive of missing data) are conservative.

[13] See, for example, Paul et al. (2010), DiMasi et al. (2013), and Hay et al. (2014).

[14] When animal testing costs occurred in a year during which costs were incurred for two clinical phases, the animal costs were allocated to the two phases according to their relative costs for the year.

[15] Averages for unweighted costs did not differ greatly from the weighted cost figures. On an unweighted basis, mean phase I, phase II, and phase III costs were $29.7 million, $64.7 million, and $253.5 million, respectively.

[16] The ratios for median costs for the current study are 11.6 for phase III relative to phase I, 4.5 for phase III relative to phase II, and 2.6 for phase II relative to phase I. The corresponding ratios for the previous study are 4.5, 3.6, and 1.2, respectively.

[17] In real terms, median phase I cost was actually 4% lower for the current study compared to the previous study.

Table 2
Average out-of-pocket clinical period costs for investigational compounds (in millions of 2013 dollars).[a]

Testing phase	Mean cost	Median cost	Standard deviation	Standard error	N[b]	Probability of entering phase (%)	Expected cost
Phase I	25.3	17.3	29.6	3.0	97	100.0	25.3
Phase II	58.6	44.8	50.8	6.6	78	59.5	34.9
Phase III	255.4	200.0	153.3	34.1	42	21.1	54.0
Total							114.2

[a] All costs were deflated using the GDP implicit price deflator. Weighted values were used in calculating means, medians, and standard deviations.
[b] *N* = number of compounds with cost data for the phase.

Table 3
Nominal and real cost of capital (COC) for the pharmaceutical industry, 1994–2010.

	1994	2000	2005	2010
Nominal COC (%)	14.2	14.9	13.3	11.4
Inflation rate (%)	3.1	3.1	2.5	2.0
Real COC (%)	11.1	11.8	10.8	9.4

corresponding figures for the previous study were 36.9% for phase I, 50.4% for phase II, and 12.6% for phase III/regulatory review.

5.2. Cost of capital estimates

To account for the time value of money in our previous paper (DiMasi et al., 2003), we utilized an 11% real after-tax weighted average cost of capital (WACC). In particular, we employed the capital asset pricing model (CAPM) to estimate the cost of equity capital. This was combined with the cost of debt, appropriately weighted with the cost of equity, to yield a representative, pharmaceutical industry weighted after-tax cost of capital. The resultant parameters were estimated at regular intervals from the mid-1980s to the year 2000, given the time period spanned by our sample of R&D projects.

In the present paper, we follow the same methodology to compute WACC. In the current R&D cost analysis, we have a sample of new drugs that began clinical trials in 1995 through 2007 and which have an average introduction period in the latter part of the 2000 decade. Hence, a relevant time period for our cost of capital is the mid-1990s through 2010. Our analysis yielded an after-tax weighted cost of capital of 10.5%, moderately lower than in our last paper. This reflects the fact that the cost of equity capital has declined in pharmaceuticals since 2000 (as well as for other industrial sectors). Research intensive industries, including the pharmaceutical industry, generally finance most of their investments through equity, rather than through debt. This is the case even when the cost of debt is significantly below the cost of equity (Hall, 2002; Vernon, 2004). One of the primary reasons is that servicing debt requires a stable source of cash flows, while the returns to R&D activities are skewed and highly variable (Scherer and Harhoff, 2000; Berndt et al., 2015). Given the low debt-to-equity ratios that exist for pharmaceutical firms, the cost of equity component dominates the computed WACC values in Table 3.

To obtain a real cost of capital, we first compute the nominal values and then subtract the expected rate of inflation. The nominal cost of capital in 1994 is from a CAPM study by Myers and Howe (1997). The estimates for 2000, 2005, and 2010 are based on our own analysis, utilizing a comparable approach, with a large sample of pharmaceutical firms.[18] As this table shows, the estimated nominal cost of capital for pharmaceuticals was fairly stable during the period 1994–2000 (14.2–14.9%). However, it decreased during the decade of 2000s, particularly after the global recession occurred (with a value of 11.4% observed in 2010).

As discussed in DiMasi et al. (2003), the rate of inflation was above historical values during the first part of the 1980s, but then receded back to or below historical levels throughout most of the 1990s. Hence, we utilized the long run historical value for inflation for the expected inflation level in 1994 and 2000 (3.1%), as in our prior work. For the 2000s decade, inflation was significantly below historical values. In this case, we employed a 5-year lagged moving average to compute the expected rate of inflation in 2005 and 2010 (calculated as 2.5% and 2.0%, respectively).

As shown in Table 3, our estimates for the real cost of capital varied between 9.4% and 11.8% for pharmaceutical firms over the 1994–2010 period. We elected to use the midpoint of this range, or approximately 10.5%, as the representative COC to capitalize our R&D cost estimates.

The focus of our analysis is R&D investment expenditures and privately financed resources for new drugs undertaken by the biopharmaceutical industry. Accordingly we capitalized these expenditures utilizing a cost of capital estimate based on financial data from publicly listed firms. Drug development is also sponsored and funded by government and non-profit agencies (e.g., public–private partnerships devoted to developing medicines for neglected diseases). To the extent that our cost estimates are applicable to these ventures, a social rate of discount would be appropriate to capitalize R&D outlays. We provide a sensitivity analysis in Section 6 with respect to a wide spectrum of alternative cost of capital values.

5.3. Capitalized clinical cost per investigational drug

Opportunity cost calculations for clinical period expenditures require estimates of average phase lengths and average gaps or overlaps between successive clinical phases to generate an average clinical development and regulatory review timeline. Mean phase lengths and the mean lengths of time between successive phases are shown in Table 4, along with the associated capitalized mean phase costs and capitalized expected phase costs by phase for investigational compounds. The time between the start of clinical testing and submission of an NDA or BLA with the FDA was estimated to be 80.8 months, which is 12% longer (8.7 months) than the same period estimated for the previous study. The average time from the start of clinical testing to marketing approval for our timeline was 96.8 months for the current study, 7% (6.5 months) longer than for the earlier study. The difference is accounted for by shorter FDA approval times. The period for the previous study included, in part, a period prior to the implementation of the *Prescription Drug User Fee Act of 1992* (PDUFA), and, in part, the early user fee era for which approval times were somewhat higher than for later user fee periods (Berndt et al., 2005).[19] While the approval

[18] The sample is composed of all publically traded drug firms in the *Value Line Survey* which also provides beta values and the other pharma-specific parameters used in the CAPM calculations for the relevant years. The long-term horizon equity risk premium, and the yield on long-term government bonds employed in the CAPM analysis, are from Ibbotson Valuation yearbooks for 2000, 2005, and 2010.

[19] The user fee legislation sunsets every 5 years. It has been renewed every 5 years since its original enactment. Performance goals for FDA review of marketing

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