

A version of this paper appeared at Research Policy Journal (vol. 40 pp. 1170-1187 Nov. 2011)
Research Policy (2011), doi: 10.1016/j.respol.2011.05.021
<http://dx.doi.org/10.1016/j.respol.2011.05.021>

**US Biopharmaceutical Finance
and
the Sustainability of the Biotech Business Model**

William Lazonick and Öner Tulum*

September 2011

* William Lazonick is a professor at the University of Massachusetts, and President of The Academic-Industry Network (www.theAIRnet.org), where Öner Tulum is a research associate. Previous versions of this paper were presented at the 25th DRUID Celebration Conference 2008, Copenhagen, Denmark, June 20, 2008; the Industry Studies Association Conference, Chicago, Illinois, May 29, 2009, and the Atlanta Conference on Science and Technology, October 2, 2009. We acknowledge the important contributions to this project of Edward March, Visiting Professor of Engineering, Dartmouth College and formerly Executive-in-Residence at UMass Lowell, as well as Mustafa Erdem Sakinc, and Yue Zhang, both former RESD Master's students. He Gao, Jon Latner, Shuwen Liu, and Dimitra Paparounas also provided research assistance. Christina Bermingham helped us to spot errors in the text. Three anonymous reviewers for Research Policy provided us with insightful comments that help us to improve the argument. We are grateful to former Chancellor William Hogan, former Executive Vice-Chancellor Frederick Sperounis, and former Provost John Wooding of the University of Massachusetts Lowell for supporting this project. Funding was also provided by the ESEMK project of the European Commission under the 6th Framework Programme (contract CIT2-CT-2004-506077). This project is now being supported with funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under Socio-economic Sciences and Humanities, grant agreement n° 217466, as well as by the Ford Foundation as part of the project, Financial Institutions for Innovation and Development and by the Institute for New Economic Thinking as part of the project, The Stock Market and Innovative Enterprise.

© 2011 William Lazonick and Öner Tulum

Abstract

In the decade before the 2008 economic crisis, the US biotechnology industry was booming. In a 2006 book, *Science Business: The Promise, the Reality, and the Future of Biotech*, Gary Pisano implies that, given the 10–20 year time-frame for developing biotech products and the lack of profitability of the industry as a whole, the US biotech boom should not have happened. Yet the biotech industry has received substantial funding from venture capital firms as well as from established companies through R&D alliances. Why would money from venture capitalists and big pharma flow into an industry in which profits are so hard to come by? The purpose of this article is to work toward a solution of what might be called the “Pisano puzzle”, and in the process to provide a basis for analyzing the industrial and institutional conditions under which the growth of the US biopharmaceutical (BP) industry is sustainable. One part of the answer has been the willingness of stock-market investors to absorb the initial public offerings (IPOs) of a BP venture that has not yet generated a commercial product, and indeed may never do so. The other part of the answer is that the knowledge base that BP companies can tap to develop products comes much more from government investments and spending than from business finance. Indeed, we show that, through stock buybacks and dividends, established corporations in the BP industry have been distributing substantial sums of cash to shareholders that may be at the expense of R&D. We use the framework that we have developed for analyzing the sustainability of the US BP business model to pose a number of key areas for future research and policy, with an emphasis on the implications of the financialization of this business model for the generation of safe and affordable BP drugs as well as the need for a theory of innovative enterprise.

1. The “Pisano Puzzle”

In the decade before the recent economic crisis, the US biotechnology industry was booming. According to Ernst & Young’s annual global biotechnology reports¹, measured in 2008 dollars, US biotechnology revenues increased from \$20 billion in 1996 to \$70.1 billion in 2008, while R&D spending in the industry increased from \$10.8 billion to \$30.4 billion. In 1996 the industry had 1308 biotech firms, of which 260 were publicly listed; and in 2008, 1754 companies, of which 371 were publicly listed. Employment in the industry increased from 118,000 in 1996 to a peak of 198,300 in 2003, before declining to 187,500 in 2004 and 170,500 in 2005, and then rising again to 190,400 in 2008.

In a book, *Science Business: The Promise, the Reality, and the Future of Biotech*, published in 2006, Gary Pisano, a long-time student of the biotech industry, implies that, given the lack of profitability of the industry as a whole, the US biotech boom should not have happened. The development of biotech drugs requires the organizational integration of diverse capabilities in a cumulative learning process that can take 10–20 years to yield a commercial product with highly uncertain prospects for success. In a Harvard Business Review article, adapted from the book, Pisano (2006a, pp. 114–115) observes that after 30 years “biotech still looks like an emerging sector”:

Despite the commercial success of companies such as Amgen and Genentech and the stunning growth in revenues for the industry as a whole, most biotechnology companies earn no profit. Nor are they significantly more productive at drug R&D than the much maligned behemoths of the pharmaceutical industry.

Pisano (2006b, pp. 205–209) combines data for 293 US biotech companies that were publicly held in 2004 to generate totals for revenues and operating income for these companies for 1975 through 2004. In 2004 combined revenues were \$35.8 billion and operating income \$2.5 billion. When results for Amgen – the largest dedicated biotechnology firm – are dropped from the totals, combined revenues fall to \$25.2 billion with a combined loss from operations of \$2.1 billion (Pisano, 2006a, p. 119). Moreover, one can assume that the biotech companies in existence that remained privately held in 2004 were in general less profitable than those that were publicly held.

Technological innovation in the biotech industry depends on a process of cumulative and collective learning. Yet, Pisano (2006b, p. 155) argues, “[t]he high rate of firm formation means that there are many inexperienced firms in the industry.”

The typical start-up in biotech is simply going to lack the capabilities of a Genentech, which has accumulated R&D experience for more than thirty years. In addition, because newer ventures have limited financial resources, they simply cannot afford to learn from experience.... [G]iven that venture capitalists are focused on a liquidity event in a three-year time frame, they have little incentive to promote learning at the organizational level. Finally, the market for know-how may also impede learning from experience. The average R&D alliance in biotechnology lasts less than four years (about one-third the expected product development cycle). Alliance partners are interested in the firm achieving its next milestone, not in building long-term capabilities. If the biotech firm cannot achieve its milestones, the partners have an easy option to terminate the relationship.

In other words, given its current organization, Pisano sees the US biotech industry as beset by “short-termism”, whereas what this industry needs more than any other is “patient capital”.

Given these characteristics of the industry, one would think that biotech would have had difficulty securing investment finance from the business sector. Yet as Pisano (2006b, Ch. 8) himself shows, biotech has

¹ See www.ey.com/beyondborders for the latest report.

received substantial funding from venture capital firms. For the period 1978 through 2004, measured in 2004 dollars, venture capital invested \$38 billion in US biotechnology companies. About two-thirds of the venture capital investment (measured in 2004 dollars) occurred after 1998, with 27% in 2000 and 2001 alone (Pisano, 2006b, p. 141).

Once these new ventures are formed, moreover, they often receive funding from R&D alliances with established pharmaceutical companies. Average annual expenditures (in 2006 dollars) on corporate partnering in the biotech industry, of which R&D alliances are an important form, increased from \$7.9 billion in 1999–2001 to \$10.0 billion in 2002–2004 to \$17.2 billion in 2005–2006 (Burrill, 2005; Rosen, 2006). An R&D alliance typically includes an R&D contract from the established company for the startup to engage in drug development in exchange for intellectual property rights and, if and when the drug is approved, certain marketing rights. For almost all young biopharmaceutical companies, R&D alliances and other forms of corporate partnering represent their major, if not only, source of income (as distinct from equity investments) prior to an IPO. An R&D alliance also typically includes a capital injection into the startup that gives the established company an equity stake.

Hence what might be dubbed the “Pisano puzzle”: why would money from venture capitalists and big pharma flow into an industry in which profits are so hard to come by? The purpose of this article is to work toward a solution of this puzzle, and in the process to provide a basis for analyzing the industrial and institutional conditions under which the growth of the US biopharmaceutical (BP) industry is sustainable.

One part of the answer, which we explore in Section 2 of this paper, is the willingness of stock-market investors to absorb the initial public offerings (IPOs) of a BP venture that has not yet generated a commercial product, and indeed may never do so. According to Pisano (2006b, p. 141), for the period 1978 through 2004, measured in 2004 dollars, public equity markets absorbed \$168 billion of IPOs and secondary stock issues by US biotechnology companies, with about two-thirds of these funds raised after 1993 and most of the money flowing into the industry in the speculative boom of 1999–2000. Besides enabling the BP venture to raise funds for further drug development, a stock-market listing also creates the opportunity for venture capitalists and other parties, such as R&D partners, with equity stakes in the BP venture to exit from their investments, often with a substantial return despite the absence of a commercial product.

The other part of the answer, which we explore in Section 3, is that the knowledge base that BP companies can tap to develop products comes much more from government investments than from business investments. We outline the modes and extent of government support for the US BP industry, emphasizing the roles of government research funding, subsidies, regulation, and spending in enabling an industry that depends on investments in a complex knowledge base to exist and grow.

Then in Section 4, we combine the analyses in the previous two sections to highlight the limits to the sustainability of the growth of the US BP industry based on its current financing model. In particular, we emphasize the financial behavior of US BP firms that, to boost their stock prices, allocate resources to stock repurchases at the expense of investments in productive capabilities and to the benefit of the corporate executives who make these allocative decisions.

Finally, in Section 5, we use the framework for analyzing the sustainability of the US BP business model to pose a number of key areas for future research and policy, with an emphasis on the implications of the financialization of this business model for the generation of safe and affordable BP drugs as well as the need for a theory of innovative enterprise.

2. The US biopharmaceutical financing model

The development of BP drugs requires a unique knowledge base that depends on intense interactions among scientists in research institutes and business enterprises. As a result, localities in which these knowledge bases have been built have become centers for new firm formation and the growth of BP firms. There are a number of main centers of BP growth in the United States, of which the Boston–Cambridge area is the most concentrated and important (see Cortright and Mayer, 2002; Feldman, 2003; Owen-Smith and Powell, 2004; Porter et al., 2006; Lazonick et al., 2007).

Venture capital has become integral to the growth of these regional BP industries. Of \$27.6 billion in venture-capital investments in the US BP industry in 2001–2006, 24.8% was in the San Francisco area, 17.6% in the Boston–Cambridge area, 12.8% in the San Diego area, and 12.4% in the New York City–Northern New Jersey area (Lazonick et al., 2007). For the BP industry as a whole, since 2000 venture-capital investment in the BP industry has been at extraordinarily high levels. Fig. 1 shows the general rise from the late 1970s to the late 1990s in the number of venture-backed biotech firms and the value of disbursements in 2009 dollars. After accelerations in both firm and disbursement levels in the last half of the 1990s, venture creation and venture funding jumped dramatically in the 2000s and have remained high throughout the decade. The average annual number of venture-backed deals increased from 225 in 1995–1999 to 291 in 2000–2004, and averaged 415 for 2005–2009; while the average annual amount of disbursements in 2009 dollars increased 2.08 times from \$1518 million in 1995–1999 to \$3167 million in 2000–2004, and averaged \$3726 million in 2005–2009.

[Insert Figure 1 about here]

The development of BP drugs is a costly process (Grabowski et al., 2002; DiMasi et al., 2003, 2005a,b; Light and Warburton, 2005a,b; Adams and Brantner, 2006). Replicating the calculations of DiMasi et al. (2003), Adams and Brantner (2006) argue that the cost of developing a new molecular entity varies between \$500 million and \$2 billion in 2000 dollars. A subsequent study by DiMasi and Grabowski (2007) estimates the average cost (in 2005 dollars) of developing biologics as \$1.24 billion and pharmaceuticals as \$1.32 billion. The US BP industry has adopted the formula (suggested by Ligand Pharmaceuticals) that during the first decade of its existence 10% of a BP firm's funding comes from venture capital, 50% from R&D alliances with established pharmaceutical companies, and 40% from public equity markets (Hess and Evangelista, 2003; see also Lerner et al., 2003).

A study by Cortright and Mayer (2002) found that, across nine major metropolitan areas in the United States, R&D alliances accounted for \$769 million in funding prior to 1990, \$4481 million from 1991 through 1995, and \$9798 million from 1996 through 2001. Data already cited suggests that for the United States as a whole average annual expenditure on R&D alliances was more than two times greater in 2005–2006 than it had been in 1999–2001 (Burrill, 2005; Rosen, 2006). In entering into an R&D alliance, the “startup” (which may have been in existence for decade or more) gives up certain property rights to its drug, if and when it is ever approved for sale (Wakeman, 2004, 2008). Typically the startup is able to use the revenues and capital injections from one or more R&D alliances to convince stock market investors that it is worthy of an IPO (as we show in the example of Affymax below). Subject to achieving milestones, the R&D alliances can continue to provide income after the IPO (see also Nakajima and Loveland, 2007). Alternatively, R&D alliances can provide the funding for a startup to develop its drug to the stage at which an established company deems it worthwhile to acquire it, even though a commercial drug has yet to be generated.

Virtually all BP companies that do IPOs are product-less. Pisano (2006b, p. 143) argues that “only approximately 20% of all publicly held companies in existence today have any products on the market or are earning royalties based on products commercialized by partners. Thus the vast majority of publicly held biotech firms are essentially R&D entities.” Schiff and Murray (2004) underline the importance of

Special Purpose Entities (SPEs) and the role that they have played in developing several blockbuster drugs. Since the early 1980s investments in R&D have been made through SPEs in which a technology developer (inventor) and a sponsor (investor) each have equity stakes in a new joint venture founded in the form of an R&D limited partnership or Special Purpose Corporation (SPC). Through this strategy, the technology developer gives up certain intellectual property rights by transferring part of the technology to the new SPE and generating the finance necessary for further R&D activities. Special Purpose Accelerated Research Corporation (SPARC) and Stock and Warrant Off-Balance-Sheet Research and Development (SWORD) are two well-known brand names of SPEs. Companies such as Amgen, Genzyme, Genentech, and Biogen made use of SWORD to finance the initial phase of the R&D processes that ultimately generated blockbusters (Solt, 1993; Schiff and Murray, 2004).

If, to generate returns on their investments, venture capitalists and established pharmaceutical companies had to wait for a BP drug to be approved for sale on the market, they may not have made the investments in the first place. Rather than waiting 10–20 years to see whether a commercial drug will in fact be produced, the existence of a speculative stock market provides them with a mode of exit from their investments by means of an IPO. Fig. 2 shows the number and value (in 2009 dollars) of venture-back BP IPOs in the United States from 1979 through 2009. As can be seen, venture-capital investments are highly variable from year to year, with sharp peaks in 1983, 1986, 1992, 1996, 2000, and 2004.

[Insert Figure 2 about here]

Alternatively, equity holders can exit through the private sale of the startup to an established company, receiving payment in cash or in the company's listed shares. As Fig. 3 shows, such M&A deals have become particularly important as a mode of exit in the 2000s. Indeed, in 2006–2009 the average value of an M&A deals far surpassed the average value of an IPO. Further research will be required to determine whether, as one would assume, the startups that do M&A deals are further advanced toward the development of a commercial drug, and hence less speculative investments.

[Insert Figure 3 about here]

The speculative character of these investments is confirmed in Fig. 4, which shows the relation between the annual average movements of the NASDAQ Composite Index and the value of venture-backed BP IPOs in current dollars. Especially over the past decade, it would appear that stock market speculation has been a critical inducement to venture financing of the BP industry. By the same token, the recent financial crisis lowered expectations of returns from IPOs (Moore, 2008). In 2008, 2009 and the first half of 2010 there was only one venture-backed IPO in the US biotech industry.

[Insert Figure 4 about here]

As an example of the relation between venture financing, R&D contracts, and IPOs, on December 15, 2006, Affymax (AFFY), a venture-backed BP company based in Palo Alto, California that had been created in 2001 as a spinout from GlaxoSmithKline, did an IPO, raising \$92 million (Lorenzo, 2006).² From its founding to its IPO, Affymax recorded a total of \$11.7 million in revenues, virtually all of it from an R&D partnership worth up to \$102 million, inked in February 2006, with Japan-based Takeda Pharmaceutical (Phil-Carey, 2006). At that time, Affymax had a therapeutic product under development in the late stages of Phase II clinical trials, with the expectation of moving into Phase III trials in early 2007 and the possibility of gaining Food and Drug Administration (FDA) marketing approval for the drug in 2010; that is, 3–4 years after the IPO. At that point, Takeda would have exclusive rights to market the drug outside of the United States. But Takeda, as well as Affymax's venture capitalists, did not have to wait

² Affymax had actually been founded in 1988 in The Netherlands with a research lab in Palo Alto, California. GlaxoSmithKline acquired Affymax in 1995 (Kornberg, 1995, pp. 93–94).

until a product actually went to market to generate returns from their investments. As part of the R&D partnership, Takeda purchased 2.1 million Affymax shares for \$10 million in February 2006. At the IPO some 10 months later, Takeda's shares were worth \$63 million.

Takeda was able to reap this return on its shareholdings because of the existence of public investors who were willing to speculate in the shares of a company like Affymax which was still years away from a commercial product. Indeed, from an IPO price of \$30.00 on December 15, 2006, Affymax's stock rose to a peak price of \$41.00 on February 12, 2007, and then began a general decline to \$9.03 on December 23, 2008. It then rose as high as \$25.43 on December 30, 2009, and stood at \$23.01 on Friday, June 18, 2010. By the following Monday, however, the stock price collapsed to \$7.18 when it was announced that some patients had suffered heart-related side effects in Phase III trials. As can be seen in Fig. 5, even before the stock price collapse in June 2010, both the Affymax stock price and the trading volume in its shares were very volatile, with investors going into and out of the market in the attempts to lock in speculative gains. The existence of stock market investors looking to make speculative gains on a stock such as Affymax is what enables the IPO, which in turn attracts venture capital and big pharma money into the BP industry.

[Insert Figure 5 about here]

Stock speculation and manipulation is a common practice in trading a technology-based stock such as Affymax. The BP industry's complex technology and knowledge base often prevents investors from grasping the nature of the technologies employed or being developed (Aboody and Lev, 2000). But then, as the Affymax example also demonstrates, even those who have a deep understanding of the technologies involved will face uncertainty concerning the success or failure of the drug development process at its different stages. Stock-market speculators bet on the movement of a BP stock on the basis of "good news" and "bad news", often related to R&D contracts and clinical trials (see McNamara and Baden-Fuller, 2007).

Through such speculation, it is quite possible for stock-market investors to reap huge rewards by trading in BP stock, even when no commercial product is forthcoming. At some point these gains may be offset by substantial losses although, even without violating SEC insider trading laws, the distribution of gains and losses may not be random given the differential monitoring capabilities of different types of speculators. All that matters is that "greater fools" remain in the market when a speculator decides to sell his or her stock. In a period when stock prices are rising, and speculative gains are being made, all manner of "greater fools" or "noise traders" are drawn into the speculative game. Speculative investors chase stocks known as ten-baggers (those having the potential of ten times the return on the original investment) or penny stocks with the possibility for 1,000-fold growth – again based on future expectations and media coverage, but not necessarily requiring the actual commercialization of a drug (Fortun, 2001). With its lax listing requirements in terms of capitalization and a record of profitability, NASDAQ invites speculation. Harris (2006, p. 6) documents that, to compete for biotechnology stock listings and the business of "noise traders", stock exchanges such as Toronto (TSX), New York (NYSE) and London (LSE) lowered their listing standards.

At times, a stock-specific or technology-specific event may lead to an industry-wide market frenzy fed by false expectations what Shiller (2000) called "irrational exuberance" (Huberman and Regev, 2001; Wolff, 2001; Bastin and Hubner, 2006; Harris, 2006). Huberman and Regev (2001) document irrational exuberance in the case of EntreMed (ENMD), a pharmaceutical company that develops cancer drugs, which did its IPO in 1996. EntreMed's stock, listed on NASDAQ, rose seven-fold to \$85 at the opening of trading on Monday, May 4, 1998 from \$12.06 at the previous closing on Friday, May 1. The reason: an article about the company's successful cancer therapy treatment appeared in the Sunday edition of the New York Times. The substance of the article was excerpted from a journal article that had originally been published in Nature magazine on November 28, 1997. The optimism about EntreMed spilled over to biotechnology stocks more generally, with (not including EntreMed) a 7.5% increase in one trading day on

the NASDAQ combined biotechnology index (Huberman and Regev, 2001, p. 392). Subsequently, a November 11, 1998 report in the Wall Street Journal that stated that other laboratories had been unable to reproduce EntreMed's results set off a sharp decline of the company stock price, although the depressed stock price was still more than two times higher than the price on May 1, 1998.

3. US Government Support for Biotech

Pisano (2006b) does not mention the possibility that speculative investments in IPOs and secondary issues may be responsible for a substantial proportion of the venture, R&D, and public equity funds that has flowed into the biotech industry. Even then, the fact that the speculative stock market can enable financiers to reap returns on young biotech companies long before they have generated a commercial product is only one part of the solution to the "Pisano puzzle". The other part is the role of the government in the biotech industry. The US government has supported the industry through the funding of basic science through the National Institutes of Health; the relaxation of government control over the commercial use of the results of publicly funded research through, as a prime example, the Bayh-Dole Act of 1980; and the provision of strong intellectual property protection, through not only patents but also the Orphan Drug Act of 1983.³

It is only in the concluding chapter of the book, where he devotes a few pages to a discussion of "the institutions of basic science" that Pisano (2006b, p. 186) recognizes in a general way the centrality of government funding to the biotech industry:

The institutions of basic science include academic research laboratories, government research institutes, and government funding of science. These institutions have played an important role in advancing the underlying sciences of biotechnology. It is hard to imagine what the life sciences would look like today without the National Institutes of Health, the University of California, Stanford, MIT, Columbia, University of Washington, Harvard, the Whitehead Institute, the Institute of Genomic Research, the Human Genome Project, the MRC Laboratory of Molecular Biology, dozens of academic medical centers, countless other governmental and academic laboratories around the world and journals such as Science and Nature.

While Pisano calculates the cumulative flows of venture capital and stock market funds into the biotech industry for the period 1978–2004, he attempts no such parallel calculation for government funding, notwithstanding his "hard to imagine what the life sciences would be like" statement in the paragraph just quoted. In fact, from 1978 through 2004, NIH spending on life sciences research totaled \$365 billion in 2004 dollars (which can be compared with his figures for venture capital and public equity funding cited above).⁴ Moreover, unlike venture capital and stock market investments, which have fluctuated widely from year to year, NIH funding increased in nominal terms in every single year from 1970 to 2009, except for a small decline in 2006. The rate of increase in funding in real terms was particularly large in 1999–2003 when it averaged almost 12% per annum. In 2004 NIH funding in real dollars was double its level in 1994 (see Fig. 6). Since its inception in 1938 through 2009, US taxpayers invested \$696 billion in 2009 dollars in the work of the NIH. For the 33 years since 1976, when Genentech was founded as the first biotech company to take advantage of the new techniques of rDNA, NIH funding totaled \$583 billion in 2009 dollars. Through the NIH, the US government, and by extension the US taxpayer, has long been the nation's (and the world's) most important investor in knowledge creation in the medical fields. Without NIH funding to create the indispensable knowledge base, venture capital and public equity funds would not have flowed into biotech.

³ As Jaffe and Lerner (2001, p. 167) have recognized: "The United States government is by far the single largest performer and funder of research and development in the world." See also McMillan et al. (2000). In contrast to Pisano, Cockburn and Stern (2010) stress the fundamental importance of the NIH and other federal funding in the development the US biopharmaceutical industry. But they ignore the role of the financialized business model in the industry's evolution and performance.

⁴ NIH, Office of Extramural Research: <http://grants1.nih.gov/grants/award/HistoricRankInfo.cfm>.

[Insert Figure 6 about here]

The US Congress provided the NIH with a budget of \$30.2 billion in 2009 and \$30.9 billion in 2010 (in addition the NIH received \$10.2 billion in 2009–2010 under the American Recovery & Reinvestment Act). The NIH uses 10% of its budget to directly employ 6000 in its own labs, mainly at its 26 active centers and institutes in Bethesda, Maryland. More than 80% of the budget “is awarded through almost 50,000 competitive grants to more than 325,000 researchers at over 3000 universities, medical schools, and other research institutions in every state and around the world.”⁵

As one of the NIH’s 26 centers, the National Human Genome Research Institute (NHGRI), created in 1989, was allocated \$516 million in 2010, and through 2009 its funding totaled over \$7 billion in 2009 dollars. The most recent addition to the growing number of NIH centers and institutes is the National Institute of Biomedical Imaging and Bioengineering (NIBIB). It began receiving appropriations in 2002, and through 2009 had total funding of \$2.3 billion in 2009 dollars, plus \$316 million in 2010. NHGRI and NIBIB are relatively small programs within NIH, together absorbing 2.7% of total NIH funds in 2010. The top three centers, together accounting for 41.2% of the NIH’s total funds in 2010, are the National Cancer Institute (NCI) with 16.5% of the total; the National Institute of Allergy and Infectious Diseases (NIAID) with 14.6%; and the National Heart, Lung, and Blood Institute (NHLBI) with 10.0%. These knowledge-creating programs are all highly relevant to the biotech industry.

A number of important changes in government regulation in the late 1970s and early 1980s made this knowledge base both more valuable and more accessible to high-tech business interests. The powerful high-tech lobby, led by the American Electronics Association and the National Venture Capital Association, that had by the late 1970s emerged from the microelectronics industry centered in Silicon Valley convinced the US Congress to alter tax laws that provided financial incentives for the allocation of capital and labor to high-tech startups (see Lazonick, 2009a, Ch. 2). Then in the early 1980s, a number of regulatory changes, all connected with intellectual property rights, specifically encouraged new ventures in biotech. The Bayh-Dole Act of 1980 enabled biotech startups to tap the federally funded knowledge base. By giving universities and hospitals clear property rights to new knowledge that resulted from federally funded research. Bayh-Dole facilitated the transfer of this knowledge to support the creation and growth of new technology firms (Mowery et al., 2004). The motivation for Bayh-Dole was the growing number of biotech inventions that, it was argued, would be left unexploited unless the conditions for the transfer of intellectual property were made less restrictive.

In 1980 as well, the Supreme Court decision in *Diamond vs. Chakrabarty* that genetically engineered life forms are patentable greatly enhanced the opportunity for the types of knowledge transfers that Bayh-Dole envisioned. The decision itself was a five to ruling, and has since been the subject of debate (Lewin, 1982; Eisenberg, 2002; Garcia, 2002). It has also been documented that many interest groups, including Genentech, the Pharmaceutical Manufacturers Association, the American Patent Law Association, the New York Patent Law Association, American Society for Microbiology, and the University of California San Francisco (as a single brief that included files from American Society of Biological Chemists, the Association of American Medical Colleges, the California Institute of Technology, and the American Council on Education) filed briefs with the Supreme Court to support a ruling in favor of *Chakrabarty* that would enable a gene to be patented (Kevles, 1998). In the early 1990s, in the context of the Human Genome Project, even the NIH began patenting partial complementary DNA sequences on the grounds that patent licenses to biotech companies would encourage product development (see Eisenberg, 1992).

In the 1980s patent protection for genetically engineered organisms was important for inducing money and people into biotech startups in the United States (Adler, 1984; Arora and Gambardella, 1994). But it has been argued that the wide scope of IP protection in biotechnology hinders follow-on innovation by limiting

⁵ <http://www.nih.gov/about/budget.htm>.

new entrants who would compete to produce better and cheaper drugs (Merges and Nelson, 1990; Ko, 1992; National Research Council, 1997; Heller and Eisenberg, 1998; Coriat and Orsi, 2002; Walsh et al., 2006). Recently, Orsenigo et al. (2006, p. 412) have argued that there is no evidence to confirm that the expectation or experience of high profits from strong IP protection accelerates research efforts to develop new drugs and treatments. Indeed, the new evidence suggests that innovative outcomes in BP development are fundamentally dependent on the innovative capabilities of firms, and that, in the absence of firm-level capabilities to absorb new technologies and to translate them into innovative products and processes, strong IP protection is bound to fail to produce the intended results (Orsenigo et al., 2006, p. 413).

In 1982 the Small Business Administration (SBA) started the Small Business Investment Research (SBIR) program, whereby federal research agencies, including the NIH, set aside 2.5% of their extramural R&D budgets for grants to small businesses. In 1992 the SBA established the Small Business Technology Transfer (STTR) program, with set asides of 0.30% of an agency's extramural R&D budget to fund the collaboration of small businesses with federal research efforts (Audretsch, 2003; Wessner, 2009). In 2010 the NIH's SBIR awards totaled \$616 million and STTR awards \$74 million.⁶

In 1983 the passage of the Orphan Drug Act (ODA) provided another important inducement to biotech investment. Designed to encourage pharmaceutical companies to invest in the development of drugs for "rare" diseases, ODA gives companies generous tax credits for research and experimentation as well as the possibility of market exclusivity for 7 years from the time that a drug is approved for commercial sale by the FDA.⁷ It was argued that without these financial incentives many potential medicinal drugs that could be developed for relatively small markets would remain "orphans": companies would not have been willing to make the large financial commitments required to nurture these drugs from infancy to adulthood. Through 2009, the FDA designated 2113 orphan drug submissions and had granted market exclusivity on 342 drugs that had reached approval (see Fig. 7).

As shown in Fig. 7, the annual number of designations climbed in the 1980s to reach a local peak of 88 in 1990, with an annual average of 79 over 1988–1991. The annual average fell to 56 in 1992–1997, and then rose somewhat to 70 in 1998–2002. Since 2003 the annual numbers of designations have reached new heights, with a record 165 in 2008 and the annual average has been 133 over 2003–2009. The 24 approvals in 1996 remain an all-time annual high, while the six approvals in 2001 were the fewest since 1986. From 2002 to 2009, the average annual number of approvals was 16. Given the high levels of designations since 2003, we can expect that approvals will be at much higher levels over the next decade or so.

[Insert Figure 7 about here]

An orphan drug may or may not be covered by a patent. In its original formulation in 1983, the Act only covered drugs that were not patentable, but an amendment to the Act in 1985 made patented drugs potentially eligible for Orphan Drug benefits as well. While the duration of a patent is for 20 years and market exclusivity under ODA is only seven, the latter becomes effective once a drug has already been approved by the FDA for sale while, given the typically long duration of the drug development process, a patent may well be close to expiration, or even have expired, by the time a drug is ready to be sold to the public.

What makes a disease "rare"? The Act of 1983 defined a rare disease as one that "occurs so infrequently in the United States that there is no reasonable expectation that the cost of developing and making available . . . a drug . . . will be recovered from sales in the United States (Hogan, 1995, p. 534). In an amendment to the Act in 1985, the definition was changed to either a disease that affects less than 200,000 people, or, if it

⁶ http://grants.nih.gov/grants/funding/sbirsttr_programs.htm. Established in 1953, the SBA had been important to the development of the venture-capital industry through subsidies to Small Business Investment Companies (SBICs) (Kenney and Florida, 2000, pp. 106–109).

⁷ <http://www.fda.gov/orphan/oda.htm>.

affects more, a disease for which a drug cannot be developed profitably. A company retains its right to market exclusivity even if the number of people with the disease becomes greater than 200,000 during the seven-year exclusivity period.

Moreover, a company can file for orphan drug designation for multiple indications of the same drug. For example, an orphan drug designation for “the treatment of chronic myelogenous leukemia” that Novartis obtained on January 31, 2001 was approved by the FDA, with market exclusivity, on May 10, 2001 under the tradename Gleevec. During the last 5 months of 2005 Novartis filed for five other orphan drug designations, and won approval for all five on October 19, 2006, each one under the tradename Gleevec. There may be long time-lags between an original orphan drug designation and subsequent ones for the same drug. For example, in 1988 the Danish pharmaceutical company, NovoNordisk, received an orphan drug designation for “the treatment of bleeding episodes in hemophilia A or B patients with inhibitors to Factor VIII or Factor IX”, which was approved by the FDA in 1999 and marketed under the tradename NovoSeven. In 2004 NovoNordisk filed for seven more indications for NovoSeven, of which three won FDA approval in 2005.

In addition, a company that has received FDA approval for an orphan drug may subsequently find that it has one or more non-orphan applications. For example, Allergan filed for two orphan drug designations in 1984, one in 1986, and one in 1991 for a drug known as Botox. FDA approval for the two 1984 designations came in 1989 and for the 1986 designation in 2000. The indication approved in 2000 was for “treatment of cervical dystonia in adults to decrease the severity of abnormal head position and neck pain associated with cervical dystonia”. But Allergan had also discovered that Botox could be used for “the temporary treatment of moderate to severe frown lines between the brows”,⁸ and had made the drug a leader in cosmetics. The company also markets Botox as a treatment for severe under arm sweating. Indeed, according to Allergan (2008 10-K, 8), Botox “is currently approved in 75 countries for up to 21 unique indications.” In 2009 Botox generated \$1310 million in revenues (representing 29% of the company’s product sales), of which therapeutic uses were 52% and cosmetic uses the other 48% (Allergan, 2009 10-K, 3, 67).

A brochure published in June 2005 by the Genetic and Rare Diseases Center of the NIH states that there are more than 7000 rare diseases that afflict a total of 25 million Americans – or 1 in 12 of the total population and an average of about 3600 people per rare disease (NHGRI and ORD, 2005). The National Organization for Rare Disorders (NORD) database contains reports on 1150 rare diseases.⁹ Rare diseases are often genetic, and, especially given that its enactment coincided with the first wave of biotech startups, ODA has been of particular importance to small biotech companies. One role that NORD has played has been to encourage large pharmaceutical companies that have been reluctant to use their proprietary knowledge to develop specific orphan drugs to license that knowledge to smaller companies (Meyers, 2000).

Table 1 shows the number of orphan drug designations and approvals of companies that as of the June 2009 had control over at least 15 designations, including designations obtained by companies that subsequently were acquired. The 21 companies listed in Table 1 accounted for 29% of the 2189 designations and 50% of the 345 approvals from 1983 through June 18, 2010. Among these companies are many of the world’s largest pharmaceutical companies such as Novartis, Roche, Johnson & Johnson, Glaxo SmithKline, Pfizer, Bayer Schering, AstraZeneca, Merck Serono, Bristol-Meyers-Squibb, Abbott, and Novo Nordisk as well as few dedicated BP companies including Amgen, Genzyme, Biogen Idec, and Immunomedics. Dedicated BP companies MedImmune and Genentech would have been on the list had they not been acquired, respectively, by AstraZeneca in 2007 and Roche in 2009.

⁸ <http://www.botoxcosmetic.com/>

⁹ www.rarediseases.org.

Most orphan drugs are expensive. Even when the size of the market for a drug is small, the revenues can be substantial. To take some examples of leading therapeutic drugs, the average annual cost of Amgen's Epogen and Neupogen (for anemia) is \$5000 to \$20,000; Genentech's Rituxan (for rheumatoid arthritis), \$15,000–20,000; Genzyme's Cerezyme (for Gaucher's disease), \$150,000–225,000; Biogen Idec's Avonex (for multiple sclerosis), \$20,000–24,000; Merck Serono's Rebif (for multiple sclerosis), \$20,000–24,000; Gilead Sciences' AmBisone (for AIDS), over \$15,000; Novartis's Gleevec (for cancer), over \$40,500; and Millennium's Velcade (for cancer), over \$50,000 (see Caremark, 2006, p. 25; Stern and Reissman, 2006, p. 737).

Table 2 shows the dependence on revenues from drugs that have had orphan status of the leading dedicated BP companies. Note that (similar to the case of Botox outlined above) a portion of the revenues included in the “orphan drug” revenues in Table 2 are from non-orphan applications of drugs that have had orphan drug status. The point is that at formative periods in their histories, several leading biotech companies have achieved significant growth through the development and marketing of drugs with orphan status.

[Insert Table 2 about here]

As can be seen in the row labeled Total 1 in Table 2, in 2008 orphan drugs represented 59% of the total revenues and 61% of the product revenues of the six leading dedicated BP companies. Note that Amgen's two most recent blockbuster drugs, Aranesp with 2008 revenues of \$3.1 billion and Neulasta with 2007 revenues of \$3.3 billion, are second-generation low-dosage derivatives of Epogen and Neupogen respectively. If we treat these two drugs as products with “orphan” origins, then in 2008 orphan drugs were 74% of the total revenues and 75% of the product revenues of the six leading companies.

The financial histories of these companies show that orphan drugs were of even greater importance to revenues in the earlier phases of enterprise growth. More generally, the importance of orphan drugs in the growth of the BP industry can be seen by comparing the timing and growth of revenues for orphan and non-orphan blockbusters, as is done in the two panels of Fig. 8. Comparing the two panels, orphan drugs are more numerous, their revenue growth began earlier, and many of them have greater 2007 sales than the leading non-orphan drugs. If we were to transfer Amgen's Aranesp and Neulasta to the orphan drug panel, the centrality of orphan drugs in driving the development of the biotech industry would become even more apparent.

[Insert Figures 8a and 8b about here]

We have already seen an indication of the important role of big pharma in BP in Table 1 above. The growing importance of big pharma to the biotech industry, and vice versa, becomes apparent when we attach company names to the blockbuster drugs displayed in Fig. 8. Table 3 lists the companies for which these BP drugs, orphan and non-orphan, generate revenues, with big pharma in italics.

The distinction between big pharma and big biopharma has become blurred (see Galambos and Sturchio, 1998; Galambos, 2006). For both, in the 2000s, the US government still serves as an investor in knowledge creation, subsidizer of drug development, protector of drug markets, and, last but not least – as we shall discuss in the next section – purchaser of the drugs that the bio-pharmaceutical companies have to sell. The BP industry has become big business because of big government, and, as we shall now show, remains highly dependent on big government to sustain its commercial success.

[Insert Table 3 about here]

4. Sustainability of the US Biotech Business Model

On the supply side, the sustainability of the US biotech business model depends on technological innovation in the development of new drugs for the treatment of diseases, many of which were previously untreatable. Critical to this effort have been NIH funding of the life sciences knowledge base and ODA. The sustainability of the US biotech business model depends in part on the ability of the United States to continue to innovate in the BP industry, especially in the presence of an inevitable increase in global technological competition. Given government support, US BP firms need to make the investments in innovation to develop new commercial drugs.

On the demand side, the sustainability of the US biotech business model depends on the ability of those afflicted by these diseases to acquire the new biopharmaceuticals. Unlike the demand for most innovative goods and services, the demand for biotech drugs is not directly dependent on personal disposable income and consumer choice. The richer households that have the money to pay both the higher taxes needed to support public insurance plans and the higher premia needed to fund private insurance plans are not necessarily the same households that are in need of the drugs.

On the demand side, the key question is whether there will be sufficient medical coverage for the nation's population to absorb the industry's supply of BP drugs, especially when innovations in the BP industry have been transformed into approved drugs that are often very expensive. The richest nation in the world is straining to afford the wonders of modern medical technology. Prescription drug expenditures (PDE) increased as a proportion of national health expenditures (NHE) from 5.2% of GDP in 1960 to 9.1% in 1980 and 13.8% in 2000, and continued their climb to 16.2% in 2008. A rapidly increasing component of the rise in NHE is prescription drugs. Since 1981, when they reached a low for the whole period of 4.6%, PDE as a proportion of NHE have been on the rise, averaging a record 10.7% for the period 1998–2008.

An increasing proportion of NHE has been borne by public funds. Government expenditure as a proportion of NHE was 24.8% in 1960 but jumped to 37.7% in 1970 as a result of the introduction of Medicare and Medicaid in 1965 as policy pillars in the "War on Poverty" (NCHS, 2006, p. 374). This proportion stood at 42.0% in 1980, 40.2% in 1990, and 44.1% in 2000. In 2008 the government share of NHE was 47.3%.

Plan D of Medicare, introduced on January 1, 2006 to implement the Medicare Prescription Drug, Improvement and Modernization Act of 2003, further increased PDE. In total, at the beginning of January 2008, 39.6 million people received comprehensive prescription drug coverage under Medicare, including 24.4 million under Plan D, of which over 9 million were low-income beneficiaries who receive the drugs at little if any cost (O'Sullivan, 2008, p. 39; see also Montgomery and Lee, 2006; CMS, 2007).

More generally, as a proportion of GDP, the United States spends far more than any other nation on health care; in 2006 the US figure was 15.3%, followed by Switzerland at 11.3%, France at 11.1%, and Germany at 10.4% (www.who.int/whosis/data/Search.jsp). As was shown in Fig. 7, in the United States the past few years have seen a quantum increase in the number of orphan drug designations, which means that there are greater numbers of drugs for genetic and rare diseases in the pipeline. Moreover, with some 7000 such diseases having been identified and an estimated 25 million Americans who can potentially make use of them, the need for new drugs remains far from being met. In the past decade the limits to effective demand for BP drugs in the United States have been transcended to some extent through exports (Lazonick et al., 2007). Europe is the biggest foreign market for US BP exports. Among Harmonized System (HS) six-digit export classifications, the second largest product category to the EU15¹⁰ in 2009, with 5.1% of the total, was "Other medicaments, packaged for retail sale" (HS-300490). Of US HS-300490 exports to the world, 57% went to the EU15. The seventh largest product classification, with 3.6% of the EU15 total, was

¹⁰ Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom.

“Antisera and blood fractions/immunological products” (HS-300210); that is, materials for the manufacture of BP products. Of US HS-300210 exports to the world, 80% went to the EU15. In 1997 these two classifications combined had accounted for only 1.6% of all US exports to the EU15; a decade later, 8.7%.

The sustainability of the growth of the BP industry in the United States, therefore, depends in part on whether US BP firms can continue to capture European demand. In 2001 the European Union passed its own Orphan Drug Act as part of an effort to catch up to the United States in biopharmaceuticals (Young, 2007; Heemstra et al., 2008). Reflecting perhaps a process of European import substitution in BP, US exports of hormones (HS-293790), which had risen from 0.02% of all US exports to the EU15 in 1996 to 0.97% in 2004, fell sharply to 0.59% in 2005 and were down to 0.45% in 2007 and 0.26% in 2009. According to the Ernst & Young annual biotech report, in 2009 Europe had more biotech companies than the United States (1790–1699), although the United States had more than twice as many publicly listed companies than Europe (313–171). The US BP industry has had access to much more venture financing than the European industry, but the Europeans are catching up (Ernst & Young, 2010, p. 58).

Many leading European pharmaceutical companies are tapping into US biotechnology research through R&D alliances, acquisitions of US companies, and R&D facilities in the United States. For example, in 2002, Novartis, the Swiss pharmaceutical company, established its worldwide R&D headquarters in Cambridge, Massachusetts, next to MIT (Griffith, 2002). As already mentioned, the regional concentrations of biotech research and companies that can be found in the vicinity of Boston–Cambridge, San Francisco, San Diego, and Washington–Baltimore are of utmost importance to the commercialization of the findings of NIH-funded knowledge base (see Cortright and Mayer, 2002; Owen-Smith and Powell, 2004; Porter et al., 2006), and remain a distinctive source of competitive advantage for the firms that operate in these dynamic industrial districts. Nevertheless, given the European presence in the US BP industry, we can expect that the latest knowledge and cutting-edge technology will continually flow from the United States to Europe.

The subsidies and protection provided by ODA along with the NIH-funded knowledge base and non-orphan patent protection will continue to entice the business sector, including venture capital, to invest in an industry characterized by extraordinarily long product development cycles with highly uncertain prospects for commercial success. Such will especially be the case if, as we have argued, venture capitalists and established pharmaceutical companies expect that a speculative stock market will enable them to secure returns on their biotech investments long before the actual products in which they have invested generate substantial sales.

At the same time, however, the very importance of the stock market to biotech firms in particular and high-tech companies in general may serve to undermine the extent of the investments that BP companies make to generate innovative products. Over the past two decades, but especially in the past decade, the executives of US business corporations, encouraged by Wall Street, have become committed to the practice of allocating substantial corporate resources to buy back their own corporate stock (Lazonick, 2009a,b Ch. 6, 2010c).

Many of the major pharmaceutical companies and the dedicated BP companies are very active stock repurchasers. Yet in the pharmaceutical industry writ large, there has long been a debate over the high prices of prescription drugs in the United States compared with over parts of the world including Japan and the high-wage nations of the European Union. The pharmaceutical companies argue that, since so much of the research on these drugs is done in the United States, they need to charge higher prices to fund R&D. Back in 1990, President George H.W. Bush vetoed a Congressional bill to modify ODA in order to create more competition and keep down drug prices (Gibbons, 1990). In recent years Congress has been debating whether, under Plan D of Medicare, the government should use its purchasing power to step in and negotiate prices with the drug companies. Then, as now, the pharmaceutical companies have argued that

any attempt to regulate drug prices will cut into company profits, which will in turn diminish the amount of resources that companies have available to invest in R&D and, thereby, generate a flow of innovative products.

Yet, as shown in Tables 4 and 5, if one looks at the financial behavior of many big pharma and dedicated BP companies, a number of them use substantial portions of their profits to buy back their own stock. Among big pharma companies, over the period 1997–2009, Pfizer did repurchases equal to 67% of R&D expenditures, Merck 62%, and Johnson & Johnson 57%. When the substantial dividends that these companies paid over this period are added to their repurchases, the ratio of distributions to R&D shoots up to 149% at Merck, 135% at Pfizer, and 116% at Johnson & Johnson.

Table 5 charts the stock repurchase activity for 1997–2009 for leading dedicated BP companies. Amgen has repurchased stock in every year since 1992, for a total of \$14.6 billion through 2009. In many years the cost of Amgen’s stock buybacks has surpassed the company’s R&D expenditures, and for the period 1997–2009 were equal to 99% of R&D outlays.

[Insert Table 4 about here]

[Insert Table 5 about here]

Why do companies do stock buybacks? Their purpose is to raise stock prices. Prime beneficiaries of stock repurchases, and the consequent boosting of stock prices, are the high-level corporate executives who make these allocative decisions (see Lazonick, 2009a,b, 2010c). Gains from the exercise of stock options are the main component of the well-known explosion of top executive pay that has occurred since the 1980s (see Hall and Leibman, 1998; Jensen et al., 2005; Lazonick, 2010c). Table 6 shows the average gains per person from the exercise of stock options over the past decade by the CEO and other four highest paid executives of six leading dedicated biotech firms, including Amgen and Genentech. Aided by stock buybacks, the CEO and other four highest paid executives at Amgen reaped an average of \$105.7 million from gains from stock options for the period 1997–2009, while the top 5 at Genentech averaged \$116.2 million for the period 1995–2009. Among big pharma companies that are large-scale repurchasers of stock, the average gains of the top 5 from the exercise of stock options for 1997–2009 were \$32.5 million at Johnson & Johnson, \$34.3 million at Merck, and \$50.4 million at Pfizer.

[Insert Table 6 about here]

Stock buybacks represent a manipulation of the stock market, and can come at the expense of meeting the challenges of drug development. In May 2007 Amgen borrowed \$3.2 billion (\$2.0 billion due in 2008, \$1.1 billion in 2017, and \$0.9 in 2037) to help finance a \$5.0 billion stock repurchase, the largest annual purchase that the company had ever done (Amgen 10-Q, period ending June 30, 2007). At the same time, as Amgen reported in its quarterly financial filing, sales of its blockbuster anemia drug, Aranesp, declined by 19% because of an FDA ruling that dosage levels had to be cut because of cases of heart attacks from high doses (Chase, 2007).

On August 13, just after Amgen issued its second quarter 10-Q filing, an analyst at Bernstein Research wrote: “Amgen will likely lose at least 40% of their US Aranesp revenue by 2008 with even greater downside possible for both Aranesp and Epogen if upcoming [Medicare and Medicaid] reimbursement and regulatory decisions go against them.” But the analyst reportedly added: “If Amgen cuts costs, continues to buy back stock and improves its tax rate . . . it could increase its earnings per share by 10–12% each year from 2008 to 2011, even if it does not develop any significant drug candidates.”¹¹

¹¹ “Amgen moves up after analyst says company will restructure to increase earnings,” Associated Press Financial Wire, August 13, 2007.

Four days later, Amgen announced that it would reduce its workforce by 14%, or 2600 jobs, cut capital expenditures by \$1.9 billion, close some of its production facilities, and reduce R&D expenses (which had been at 27% of sales from 2003 through 2006) to 20% of sales. It may well be that Amgen borrowed money to do the \$5-billion stock repurchase because it wanted to offset the adverse impact of the Aranesp news on its stock price. In any case, the priorities of Amgen's top executives in their allocation of corporate resources seem clear.

In assessing the arguments of the relation between drug prices and BP investments in R&D, government policy makers should take seriously two salient issues that business proponents of a "free market" economy prefer to ignore. The first issue is the fact that government investment in research is more important than business investment for supporting innovation in the BP industry. The second issue is that when US BP companies get high profits from high prices they do not necessarily invest those high profits in R&D.

These two issues are intertwined. Given the role of government in funding the biotech industry, the government should take an active role in the governance of companies that make use of this support. Since the 1980s the US business community, the BP industry included, has embraced the ideology that the performance of their companies and the economy are best served by the "maximization of shareholder value" (see Lazonick and O'Sullivan, 2000; Lazonick, 2009a, Ch. 6, 2010c). It is an ideology that, among other things, says that any attempt by the government to interfere in the allocation of resources can only undermine economic performance. In practice, what shareholder ideology has meant for corporate resource allocation is that when companies reap more profits they spend a substantial proportion of them on stock repurchases in an effort to boost their stock prices, thus enriching first and foremost the corporate executives who make these allocative decisions.

5. Analyzing the Limits to the US Biotech Business Model

As outlined in this paper, and as depicted in Fig. 9, the US BP business model rests on NIH funding of the knowledge base as its foundation complemented by various types of government subsidies, of which those available to BP firms under ODA appear to be of particular importance. Building on the availability of government funding and subsidies, venture capitalists and established pharmaceutical companies provide cash for BP startups to develop drugs. In terms of the time required to develop a commercial drug, it is not unusual for the BP firm that is being funded to remain a "startup" for two decades or more. Through M&A deals and IPOs, however, the venture capitalists and the established pharmaceutical companies that fund drug development often are able to secure returns on their investments long before the BP startup actually develops a commercial drug, and in many cases even if the BP firm never develops a commercial drug (see Lazonick and Sakinc, 2010).

[Insert Figure 9 about here]

Ernst & Young's press release for its 2009 Beyond Borders biotechnology report observed that "the prolonged and systematic funding drought is placing the business model that fueled biotech growth for the past 33 years under unprecedented strain." Yet, according to Ernst & Young, in 2008 the revenues of publicly traded biotech companies grew by 12% over the previous year, reaching \$89.7 billion, and taken together these companies showed a profit. The flow of venture capital into the industry remained strong in 2008, down only 19% from a record high of \$6 billion the previous year. Meanwhile, the total value of M&A deals in biotech was \$28.5 billion, an unprecedented amount if one excludes megadeals. The Ernst & Young press release might have added that in 2008, NIH funding, the backbone of the industry, was \$30 billion, about the same as the previous year.

What then is the source of "the prolonged and systematic funding drought" that is placing the biotech business model under strain? According to Venture Xperts (see Fig. 3 above), in 2009 there was only one

venture-backed biotech IPO in the United States, worth less than \$69 million, down from 20 deals for \$1191 million in 2004, 9 deals for \$451 million in 2005, 13 deals for \$675 million in 2006, and 11 deals for \$706 million in 2007 (see also Ernst & Young, 2009, p. 24). Through the first half of 2010, there was only one venture-backed biotech IPO in the United States. In the absence of a speculative stock market that will absorb product-less IPOs, the BP business model is not providing venture capitalists and big pharma who make equity investments in BP startups with the exit opportunities that they have enjoyed in the past. The fear is that if this “funding drought” persists, the flow of venture capital and big pharma equity investments will start to dry up as well.

From the perspective that we have set out in this paper, there are a number of questions concerning the sustainability of the BP business model that require in-depth research on the sources and uses of funds that characterize the US BP business model, and on the implications of the combination of government funding and the speculative stock market for the successes and failures of companies and products over the BP industry’s history of about 35 years.¹²

- At the base of the funding structure depicted in Fig. 9, how tightly linked is NIH funding to the emergence of successful drugs, such as the blockbusters shown in Fig. 8a and b?
- How important have subsidies and protection under ODA been to successful drug development?
- As we move up the funding structure, how successful have venture capitalists and big pharma been in extracting value from their investments in startups in advance of the generation of commercial products?
- What impacts does this value extraction have on the commitment of finance to the drug development process subsequent to an IPO? Put differently, does it matter to the success or failure of the drug development process if key actors in the formation and growth of BP firms have more to gain from a speculative stock market than from the commercialization of a drug?
- Is a startup acquired through an M&A deal, that inherently becomes a real asset on the books of the acquiring drug company, of a higher quality (that is, further down the road toward developing a commercial product) than an IPO in which speculative investors in publicly traded stock can easily dispose of their investments?
- How does this mode of BP finance affect that ultimate cost of drug development, and the distribution of the costs and benefits of the drug development process?
- And when a BP company develops a profitable drug, how does a stock-market orientation, as manifested in stock buybacks and stock-based remuneration of executives, affect the commitment of finance to the further growth of the firm?

In seeking to answer these questions, our analysis is guided by “the theory of innovative enterprise”, with its focus on strategy, organization, and finance in the growth of the firm (see Lazonick, 2002, 2004, 2010a,b). The analytical framework that is derived from this theory permits us to ask how the prevailing

¹² We are doing this research as part of the European Commission’s Seventh Framework project on Finance, Innovation, and Growth (FINNOV) in collaboration with Mariana Mazzucato of The Open University; Claude Dupuy, Yannick Lung, and Matthieu Montalbon of Université Montesquieu-Bordeaux IV; and Mustafa Erdem Sakinc, formerly a graduate student in the Department of Regional Economic and Social Development of the University of Massachusetts Lowell, who is working on FINNOV as part of the Bordeaux team. As part of a project, “Financial Institutions for Innovation and Development, directed by William Lazonick, the Ford Foundation is supporting this research agenda, as is The Institute for New Economic Thinking (INET) as part of a project, “The Stock Market and Innovative Enterprise”, also directed by Lazonick. Related research on Ireland has been carried out by the authors of this paper under a collaborative agreement between the Center for Innovation and Structural Change of the National University of Ireland Galway, directed by Paul Ryan, and the UMass Lowell Center for Industrial Competitiveness under a European Commission Sixth Framework Marie Curie actions grant for the Transfer of Knowledge.

mode of finance affects the strategic decisions of those who exercise control over the allocation of the BP firm's resources as well as the organizational integration of people with diverse capabilities into the cumulative and collective learning process that is essential for successful drug development. The theory hypothesizes that the innovative performance of an enterprise will depend on (a) strategic control over allocation of the firm's resources by executives who have the abilities and incentives to develop new drugs; (b) organizational integration of the skills and efforts of key people in a hierarchical and functional division of labor into a collective and cumulative process of organizational learning that is the essence of drug development; and (c) financial commitment that provides a continuous flow of funding to the innovation process until it can generate a commercializable product that can generate financial returns. Based on the evidence that we have provided in this paper, we can hypothesize more specifically that the highly financialized US business model in the BP industry tends to undermine innovation by placing strategic control in hands of those who, primarily through stock-based compensation, have an incentive to make allocative decisions that, through speculation and manipulation, increase their firm's stock price even when such decisions impede the organizational learning processes that can result in a commercial drug. While the US BP business model has attracted tens of billions of dollars from venture capitalists, big pharma R&D contracts, and public investors over the years, these parties have provided these funds based on the possibility of a relatively quick exit through the speculative stock market rather than as committed finance in an industry in which it can take 10–20 years and upwards of \$1 billion to develop a commercial drug.

In biopharma the plausible argument has been made that companies like Amgen and Genentech became successful by gaining IP control over “the low-hanging fruit”, but that subsequent break-throughs have been hard to come by (Gillis, 1998; Fazeli, 2005; Silverman, 2006). Our contribution to this debate is to document and pose hypotheses about the influence on drug development of the highly financialized character of the US biopharma business model. Until the financial crisis of 2008, this business model brought large amounts of funding to biopharma firms through venture capital, R&D alliances, and public equity issues despite the overall lack of profitable drug development that Pisano and others point out. Meanwhile, as we have seen, in the 2000s NIH funding was substantially increased in real terms compared with the 1990s. We show that the productivity problems of US biopharma were not due to a shortage of funding. Our paper does highlight the possibility that the speculative business money that flowed into the industry before the financial crisis may have exacerbated the productivity problems of the industry because many of the financiers and entrepreneurs were able to make substantial amounts of money even without the companies in which they invested developing successful drugs. It may well be (but it is too early to tell) that if this speculative money does not return to the industry, a new, less financialized, business model might be put in place that funds fewer firms but that is more strategic in the choice of drugs to develop and more committed financially to the development of drugs that have the potential for commercial success.

As we have shown in our solution of the “Pisano puzzle”, it has been continuous government investment and subsidies combined with these speculative business funds that have financed the US BP model throughout the industry's history. By the 2000s, the ability of business interests to extract value through stock market speculation and manipulation even in the absence of value creation through innovation enabled them to take advantage of government support of the BP industry while giving little in return. The collapse of speculative markets in the financial crisis of 2008–2009 called this financialized business model into question. Nevertheless the failure of the Obama Administration to deal effectively with the financialization of the US business corporation more generally (Lazonick, 2011), combined with the persistence of US government support for the BP industry through NIH funding and ODA subsidies, suggests that the financialized business model in the US BP industry is far from dead.

References

- Aboody, D., Lev, B., 2000. Information asymmetry, R&D, and insider gains. *The Journal of Finance* 25, 2747–2766.
- Adams, C.P., Brantner, V.V., 2006. Estimating the cost of new drug development: is it really \$802 Million? *Health Affairs – MarketWatch* 25, 420–428.
- Adler, R.G., 1984. Biotechnology as an intellectual property. *Science* 224, 357–363.
- Arora, A., Gambardella, A., 1994. The changing technology of technological change: general and abstract knowledge and the division of innovative labour. *Research Policy* 23, 523–532.
- Audretsch, D., 2003. Standing on the shoulders of midgets: the U.S small business innovation research program (SBIR). *Small Business Economics* 20, 129–135.
- Bastin, V., Hubner, G., 2006. Concentrated announcements on clustered data: an event study on biotechnology stocks. *Financial Management* 35, 129–157.
- Burrill, G.S., 2005. *Biotech 2005 Industry Review & Outlook*. Burrill & Company, presentation to BioPartnering North America, February 7, available at [http://www.burrillandco.com/pdfs/BioPartnering N America.pdf](http://www.burrillandco.com/pdfs/BioPartneringN America.pdf).
- Caremark, 2006. *Trends Rx Report* (downloaded from [http://www.caremark.com/portal/asset/2006 TrendsRxReport.pdf](http://www.caremark.com/portal/asset/2006TrendsRxReport.pdf)).
- Centers for Medicare and Medicaid (CMS), 2007. US Department of Health and Human Services. Office of Public Affairs, 2007. Medicare drug plans strong and growing, January 30, (downloaded from [http://www.cms.hhs.gov/ PrescriptionDrugCovGenIn/02 EnrollmentData.asp](http://www.cms.hhs.gov/PrescriptionDrugCovGenIn/02 EnrollmentData.asp)).
- Chase, M., 2007. Amgen cuts mark biotech squeeze. *Wall Street Journal*, August 16 (downloaded from <http://online.wsj.com/article/SB118720529438898746.html>).
- Cockburn, I.M., Stern, S., 2010. Finding the endless frontier: lessons from the life sciences innovation system for technology policy. *Capitalism and Society* 5 (1), article.
- Coriat, B., Orsi, F., 2002. Establishing a new intellectual property rights regime in the United States; origins contents, and problems. *Research Policy* 31, 1491–1507.
- Cortright, J., Mayer, H., 2002. *Signs of Life: The Growth of Biotechnology Centers in the US*. The Brookings Institution Center on Urban and Metropolitan Policy.
- DiMasi, J.A., Grabowski, H.G., 2007. The cost of biopharmaceutical R&D: is biotech different? *Managerial and Decision Economics* 28, 469–479.
- DiMasi, J.A., Hansen, R.W., Grabowski, H.G., 2003. The price of innovation: new estimates of drug development costs. *Journal of Health Economics* 22, 151–185.
- DiMasi, J.A., Hansen, R.W., Grabowski, H.G., 2005a. Extraordinary claims require extraordinary evidence. *Journal of Health Economics* 24, 1034–1044.
- DiMasi, J.A., Hansen, R.W., Grabowski, H.G., 2005b. Setting the record straight on setting the record straight: response to the light and Warburton Rejoinder. *Journal of Health Economics* 24, 1049–1053.
- Eisenberg, R.S., 1992. Genes, patents, and product development. *Science* 257, 903–908.
- Eisenberg, R.S., 2002. How can you patent genes? *American Journal of Bioethics* 2, 3–10.
- Ernst & Young, 2009. *Beyond Borders: Global Biotechnology Report 2009*. EYGM Limited.
- Fazeli, S., 2005. The European biotech sector: could it achieve more? *Journal of Commercial Biotechnology* 12, 10–19.

- Feldman, M.P., 2003. The locational dynamics of the US biotech industry: knowledge externalities and the anchor hypothesis. *Industry and Innovation* 10, 311–328.
- Food and Drug Administration (US Department of Health and Human Services), 2009. List of Orphan Drug Designations and Approvals. Updated May 5, 2009, downloaded from (<http://www.fda.gov/downloads/ForIndustry/DevelopingProductsforRareDiseasesConditions/HowtoapplyforOrphanProductDesignation/UCM162066.xls>).
- Fortun, M., 2001. Mediated speculations in the genomics future markets. *New Genetics and Society* 20, 139–156.
- Galambos, L., 2006. Innovation and industry evolution: a comment. In: Mazzucato, M., Dosi, G. (Eds.), *Knowledge Accumulation and Industry Evolution: The Case of Pharma-Biotech*. Cambridge University Press, Cambridge, pp. 145–160.
- Galambos, L., Sturchio, J.L., 1998. Pharmaceutical firms and the transition to biotechnology: a study in strategic innovation. *Business History Review* 72, 250–278.
- Garcia, S.A., 2002. Patenting DNA: who defines and protects the public good? *American Journal of Bioethics* 2, 25–26.
- Gibbons, A., 1990. Orphan drug compromise Bush-Whacked. *Science Magazine* 250, 905.
- Gillis, J., 1998. Biotech's Payday Arrives: After Costly, Uncertain Start, More Firms are Turning a Profit. *Washington Post*, July 5.
- Grabowski, H.G., Vernon, J., DiMasi, J.A., 2002. Returns on research and development for 1990s new drug introductions. *Pharmacoeconomics* 20 (Suppl. 3), 11–29.
- Griffith, V., 2002. Novartis moves global research HQ to Boston. *Financial Times*, May 5.
- Hall, B.J., Leibman, J.B., 1998. Are CEOs really paid like bureaucrats? *Quarterly Journal of Economics* 113, 653–691.
- Harris, D.A., 2006. The impact of hot issue markets and noise traders on stock exchange listing standards. *University of Toronto Law Journal* 56, 223–280.
- Heemstra, H.E., de Vruueh, R.L., van Weely, S., Büller, H.A., Leufkens, H.G., 2008. Predictors of orphan drug approval in European Union. *European Journal of Clinical Pharmacology* 64, 545–552.
- Heller, M.A., Eisenberg, R.S., 1998. Can patents deter innovation? The anticommons in biomedical research. *Science* 280, 698–701.
- Hess, J., Evangelista, E., 2003. Pharma-biotech alliances: jockeying for position in the race to become “partner of choice”. *Contract Pharma*, September.
- Hogan, J.M., 1995. Revamping the orphan drug act: potential impact on the world pharmaceutical market. *Law and Policy in International Business* 26, 523–561.
- Huberman, G., Regev, T., 2001. Contagious speculation and a cure for cancer: a nonevent that made stock prices soar. *The Journal of Finance* 26, 387–396.
- Jaffe, A.B., Lerner, J., 2001. Reinventing public R&D: patent policy and the commercialization of national laboratory technologies. *RAND Journal of Economics* 32, 167–198.
- Jensen, M.C., Murphy, K.J., Wruck, E.G. (Eds.), 2005. *CEO Pay . . . and How to Fix It*. Harvard Business School NOM Working Paper No. 04-28. Harvard Business School, Boston (Downloaded from <http://www.nber.org/~confer/2005/si2005/cg/jensen.pdf>).

- Kenney, M., Florida, R., 2000. Venture capital in silicon valley: fueling new firm formation. In: Kenney, M. (Ed.), *Understanding Silicon Valley: The Anatomy of an Entrepreneurial Region*. Stanford University Press, California, pp. 98–123.
- Kevles, D.J., 1998. Diamond vs. Chakrabarty and beyond: political economy of patenting life. In: Thackray, A. (Ed.), *Private Science: Biotechnology and the Rise of the Molecular Sciences*. University of Pennsylvania Press, Philadelphia, pp. 65–79.
- Ko, Y., 1992. An economic analysis of biotech patent protection. *The Yale Law Journal* 102, 777–804.
- Kornberg, A., 1995. *The Golden Helix: Inside Biotech Ventures*. University Science Books, California.
- Lazonick, W., 2002. Innovative enterprise and historical transformation. *Enterprise & Society* 3, 35–54.
- Lazonick, W., 2004. The innovative firm. In: Fagerberg, J., Mowery, D., Nelson, R. (Eds.), *The Oxford Handbook of Innovation*. Oxford University Press, Oxford, pp. 29–55.
- Lazonick, W., 2009a. Sustainable Prosperity in the New Economy? *Business Organization and High-Tech Employment in the United States*. W.E. Upjohn Institute for Employment Research, Michigan.
- Lazonick, W., 2009b. The new economy business model and the crisis of US capitalism. *Capitalism and Society* 4 (2), article 4.
- Lazonick, W., 2010a. Innovative business models and varieties of capitalism: financialization of the US corporation. *Business History Review* 84, 675–702.
- Lazonick, W., 2010b. The Chandlerian corporation and the theory of innovative enterprise. *Industrial and Corporate Change* 19, 317–349.
- Lazonick, W., 2010c. The explosion of executive pay and the erosion of American prosperity. *Entreprises et Histoire* 57, 141–164.
- Lazonick, W., 2011. *The Fragility of the US Economy: The Financialized Corporation and the Disappearance of the Middle Class Working Paper*. The Academic- Industry Research Network, January.
- Lazonick, W., March, E., Tulum, Ö., 2007. Boston's Biotech Boom. Center for Industrial Competitiveness Working Paper. University of Massachusetts, Lowell, May 2007.
- Lazonick, W., O'Sullivan, M., 2000. Maximizing shareholder value: a new ideology for corporate governance. *Economy and Society* 29, 13–35.
- Lazonick, W., Sakinc, M.E., 2010. Do financial markets support innovation or inequity in the drug development process. In: Paper Presented at the DIME Workshop, *Innovation and Inequality: Pharma and Beyond*, Pisa, Italy, May 15 (Available at http://www.innovation-equity.eu/file_upload/williamlazonick_mustafa-erdem-sakinc_paper.pdf.)
- Lerner, J., Shane, H., Tsai, A., 2003. Do equity financing cycles matter? Evidence from biotechnology alliances. *Journal of Financial Economics* 67, 411–446.
- Lewin, T., 1982. The patent race in gene-splicing. *New York Times*, August 29.
- Light, D.W., Warburton, R.N., 2005a. Extraordinary claims require extraordinary evidence. *Journal of Health Economics* 24, 1030–1033.
- Light, D.W., Warburton, R.N., 2005b. Setting the record straight in the reply by DiMasi, Hansen and Grabowski. *Journal of Health Economics* 24 (5), 1045–1048.
- Lorenzo, A., 2006. Affymax completes \$92M IPO. *Bioworld Today*, December 18.
- McMillan, G.S., Narin, F., Deeds, D.L., 2000. An analysis of the critical role of public science in innovation: the case of biotechnology. *Research Policy* 29, 1–8.

- McNamara, P., Baden-Fuller, C., 2007. Shareholder returns and the exploration–exploitation dilemma: R&D announcements by biotechnology firms. *Research Policy* 36, 548–565.
- Merges, R.P., Nelson, R.R., 1990. On the complex economics of patent scope. *Columbia Law Review* 90, 839–916.
- Meyers, A.S., 2000. History of the American Orphan Drug Act. In: Speech at the International Conference of Rare Diseases and Orphan Drugs, Spain, February 18 (Downloaded from <http://www.rarediseases.org/news/speeches/span2>).
- Montgomery, L., Lee, C., 2006. Success of drug plan challenges democrats. *Washington Post*, November 26.
- Moore, G., 2008. VCs, angel investors: IPOs may be frozen until 2011. *Mass High Tech*, December 18 (downloaded from <http://thehartfordtechnologyincubator.com/Docs/MHT-VCs,%20angel%20investors-IPOs%20may%20be%20frozen%20until%202011-121908.pdf>).
- Mowery, D., Nelson, R., Sampat, B., Zledonis, A., 2004. *Ivory Tower and Industrial Innovation: University-Industry Technology Transfer Before and After the Bayh-Dole Act*. Stanford University Press, California.
- Nakajima, E., Loveland, R., 2007. *A Critical Alliance: The Biotechnology & Pharmaceutical Industries in Massachusetts*. University of Massachusetts Donahue Institute Report Prepared for the Massachusetts High Technology Council, (downloaded from http://www.mhtc.org/UMass_Donahue_Institute_BioPharma_Report_11April_FINAL.pdf).
- National Center for Health Statistics (NCHS), 2006. *Health, United States 2006*. US Government Printing Office.
- National Human Genome Research Institute (NHGRI) and Office of Rare Diseases (ORD) of the National Institutes of Health, 2005. US Department of Health and Human Services. 2005 Genetic and Rare Disorders, National Institutes of Health publication no, 05-5215, June, (downloaded from http://rarediseases.info.nih.gov/files/GARD_brochure_English.pdf).
- National Institutes of Health, 2009. *The NIH Almanac – Appropriations*. (Downloaded from <http://www.nih.gov/about/almanac/appropriations/index.htm>).
- National Research Council, 1997. *Intellectual Property Rights and Research Tools in Molecular Biology*. National Academy Press, (downloaded from <http://www.sjbiocenter.com/grid/reference/MolecularBiologyIntellectualProperty.pdf>).
- Orsenigo, L., Dosi, G., Mazzucato, M., 2006. The dynamics of knowledge accumulation, regulation, and appropriability in the pharma-biotech sector: policy issues. In: Mazzucato, M., Dosi, G. (Eds.), *Knowledge Accumulation and Industry Evolution*. Cambridge University Press, Cambridge, pp. 402–431.
- O’Sullivan, J., 2008. Medicare Plan D. Prescription Drug Benefit: A Primer. CRS Report to Congress, March 18. (Downloaded from <http://aging.senate.gov/crs/medicare12.pdf>).
- Owen-Smith, J., Powell, W.W., 2004. Knowledge networks as channels and conduits: the effects of spillovers in the Boston biotechnology community. *Organization Science* 15, 5–21.
- Phil-Carey, K., 2006. Affymax partners anemia drug in Japan for \$102m. *Bioworld Today*, February 14.
- Pisano, G.P., 2006a. Can science be a business? Lessons from biotech. *Harvard Business Review* 84 (10), 114–125.
- Pisano Gary, P., 2006b. *Science Business: The Promise, The Reality, and The Future of Biotech*. Harvard Business School Press.

- Porter, K., Whittington, K.J., Powell, W.W., 2006. The institutional embeddedness of high-tech regions: relational foundations of the Boston biotechnology community. In: Breschi, S., Malerba, F. (Eds.), *Clusters, Networks, and Innovation*. Oxford University Press, Oxford, pp. 261–299.
- Rosen, M., 2006. 2006: a great biotech financing year, unless you were going public. Wisconsin Technology Network, December 18. (Downloaded from <http://wistechnology.com/article.php?id=3565>).
- Schiff, L., Murray, F., 2004. Biotechnology financing dilemmas and the role of special purpose entities. *Nature Biotechnology* 22 (3), 271–277.
- Shiller, R.J., 2000. *Irrational Exuberance*. Princeton University Press, New Jersey.
- Silverman, E., 2006. Who took the tech out of biotech? *Nature Biotechnology* 24 (3), 255–256.
- Solt, M.E., 1993. SWORD financing of innovation in the biotechnology industry. *Financial Management* 22 (2), 173–187.
- Stern, D., Reissman, D., 2006. Specialty pharmacy cost management strategies of private health care payers. *Journal of Managed Care Pharmacy* 12, 736–744.
- Wakeman, S., 2004. IP Portfolios and R&D Firm Commercialization Strategy: Evidence from Biotechnology Alliances (downloaded at <http://elsa.berkeley.edu/~bhhall/others/Wakeman04IPPportfolios.pdf>).
- Wakeman, S., 2008. A dynamic theory of technology commercialization strategy. In: Paper to be Presented at the 25th DRUID Conference, Copenhagen, Denmark, June 17–20.
- Walsh, J.P., Arora, A., Cohen, W.M., 2006. The effects of research tool patents and licensing on biomedical innovation. In: Mazzucato, M., Dosi, G. (Eds.), *Knowledge Accumulation and Industry Evolution*. Cambridge University Press, Cambridge.
- Wessner, C.W., 2009. *Venture Capital and the SBIR Program*. National Research Council.
- Wolff, G., 2001. *The Biotech Investor's Bible*. John Wiley & Sons, New Jersey.
- Young, D., 2007. U.S., EU will use same orphan drug application. *BioWorld Today*, December 11.

Appendix: Tables 1-6

Table 1. Orphan drugs designations and approvals, companies with 15 or more designations, 1983-2010, as of June 18, 2010

Company	DES	APP	Tradenames
Pfizer (including Coley, Pharmacia, Pharmacia & Upjohn, G. D. Searle, Sugen, Upjohn, Warner-Lambert, Adria Laboratories, Lederle Laboratories, Wyeth)	62	18	<i>Zinecard, Genotropin (3), Aromasin, Atnativ, Ellence, Cyklokapron, Cerebyx, Benefix, Cordarone, Methotrexate, Mylotarg, Neumega, Novantrone, Refacto, Torisel, Idamycin, Mycobutin</i>
Roche* (including Behringer Mannheim, Genentech, Hoffmann-Laroche)	59	18	<i>Avastin(2), Roferon-A (2), Lariam (2), Hivid, Vesanoid, Zenapax, Protropin, Nutropin (4), Nutropin Depot, Pulmozyme, Rituxan, Synarel Nasal Solution</i>
Novartis (including Sandoz and Chiron)	58	21	<i>Cibacalcin, Lamprone, Zometa/Zabel, Gleevec (7), Simulect, Sandostatin LAR (3), Exjade, Proleukin (2), Tasigna, Tobi, Coartem, Ilaris</i>
GlaxoSmithKline (including Burroughs Wellcome, Genelabs, Glaxo Wellcome, Sirtris, SmithKline Beecham)	51	19	<i>Digibind, Retrovir (2), Exosurf Neonatal for Intratracheal Suspension (2,) Alkeran For Injection, Mepron (2), Flolan (2), Lamictal, Bexxar, Arranon, Triostat, Halfan, Albenza (2), Promacta, Arzerra</i>
Johnson&Johnson (including ALZA, Centocor, R. W. Johnson Pharmaceutical Research Institute, OMRIX, Scios, Scios Nova, Tibotec)	50	7	<i>Topamax, Leustatin Injection, Remicade (2), Elmiron, Doxil(2)</i>
Merck & Co.	32	6	<i>Intron A, Rebeto, Temodar (2)</i>
Amgen (including Immunex)	31	14	<i>Epogen (2), Neupogen (4), Sensipar, Leucovorin calcium (2), Leukine (2), Enbrel, Nplate, Ucephan</i>
AstraZeneca (including MedImmune)	29	5	<i>Respigam, Hexalen, Neutrexin, Ethyol (2)</i>
Genzyme (including ILEX Oncology and Peptimmune)	27	9	<i>Ceredase, Cerezyme, Thyrogen (2), Campath, Fabrazyme, Clolar, Myozyme, Mozobil</i>
Merck Serono (EMD Serono)	24	11	<i>Novantrone (3), Metrodin, Serostim, Geref, Gonal-F, Zorbitive, Luveris, Saizen, Cyanokit</i>
Sanofi-Aventis (including Hoechst Marion Roussel)	24		
Bayer Schering (including Berlex)	23	10	<i>Fludara, Betapace, Prolastin, Thrombate III, Kogenate, Gamimune N, Trasylol, Nexavar(2, Betaseron)</i>
Biogen Idec (including Syntonix)	22	2	<i>Zevalin, Avonex</i>
Immunomedics (including IBC)	22	0	
Bristol-Myers-Squibb	22	8	<i>Sprycel (2), Ifex, Vumon for injection, Megace, Blenoxane, Taxol, Droxia</i>
Abbott Laboratories (including Knoll, Solvay, Unimed)	22	4	<i>Panhematin, Humira, Chenix, Marinol</i>
Eisai, Inc	17	8	<i>Banzel, Dacogen, Didronel, Ontak, Panretin, Salagen (2), Targretin</i>
Celgene Corporation	17	5	<i>Revlimid (2), Thalomid (2), Vidaza</i>
Cephalon	16	3	<i>Provigil, Treanda, Trisenox</i>
SuperGen	15	1	<i>Nipent</i>
Novo Nordisk	15	8	<i>Norditropin (2), NovoSeven (6)</i>

DES=designations APP=approvals

Note: Data on designations and approval for each company are as of June 2010, and include designations and approvals in the name of firms that were subsequently acquired by the company.

* On March 26, 2009 Genentech became a wholly-owned subsidiary of Roche. Prior to the acquisition, Genentech had 22 designations and eight approvals.

Source: FDA 2010

Table 2. Orphan drugs as a percentage of revenues of leading biotech companies, 2007, 2008, 2009

	Total revenues, \$m			Product revenues, \$m			Orphan drug Revenues, \$m			Orphan drug revenues as % of total revenues		
	2009	2008	2007	2009	2008	2007	2009	2008	2007	2009	2008	2007
Amgen	14,642	15,003	14,771	14,351	14,687	14,311	8,001	7,992	7,459	55	53	50
Genentech	M&A	13,418	11,724	M&A	13,070	11,427	M&A	8,987	7,147		67	61
Gilead Sciences	7,011	5,336	4,230	6,469	5,084	3,733	1,151	1,024	897	16	19	21
Genzyme	4,516	4,605	3,813	4,077	4,197	3,458	2,342	2,579	1,895	52	56	50
Biogen Idec	4,377	4,098	3,172	3,153	2,840	2,137	3,416	3,331	2794	78	81	88
Cephalon	2,192	1,975	1,773	2,151	1,944	1,727	2,492	2,127	1704	114	108	96
Millennium	M&A	M&A	528	M&A	M&A	528	M&A	M&A	397			
TOTAL 1	32,738	44,434	40,011	30,201	43,279	38,798	17,402	26,225	21,275	53	59	53
TOTAL 2*	32,738	44,434	40,011	30,201	43,279	38,798	23,409	32,662	27,889	72	74	70

Sources: Company SEC filings and annual reports

Orphan drug revenues by company and tradename (2009, 2008 and 2007 sales in \$millions in parentheses):

Amgen: Enbrel (3493; 3598; 3230), Epogen (2569; 2456; 2489), Neupogen (1288; 1341; 1277); Sensipa (651; 597; 463)

Genentech: Rituxan (2851; 2285), Avastin (2908; 2296), Herceptin (1819; 1287), Nutropin (375; 371), Tarceva (457; 417), Activase (275; 268) Pulmozyme (302; 223)

Gilead Sciences: AmBisome (299; 289.7; 263); Letairis(184; 112.9; 21.0); Viread (668; 621.2; 613.2)

Genzyme: Cerezyme (793; 1239; 1133), Fabrazyme (429.7; 494.3; 424), Thyrogen (171; 148.4; 114), Thymoglobolin (183.3; 149.1; 127), Campath/Clolar/Mozobil (285; 101.2; 65); Myzyme (325; 296.2; 200.7); Aldurazyme (155; 151.3; -)

Biogen Idec: Avonex (2322; 2202.6; 1,868), Rituxan (1094; 1128.2; 926.1)

Cephalon: Provigil (1024; 988.4; 852) Treanda (222; 75.1; -)

Millennium: Velcade (-, -, 265) (\$397m figure includes revenues from strategic alliances and royalties)

Note: In May, 2008, Millennium was acquired by Takeda Pharmaceutical Company Limited; In March 2008 Genentech was acquired by Roche.

* Total 2 treats Amgen's Aranesp (2652; 3119; 3614) and Neulasta (3355; 3318; 3000) as derivative of orphan drugs.

Table 3. Companies with blockbuster biopharmaceutical drugs through 2009

ORPHAN BLOCKBUSTERS		NON-ORPHAN BLOCKBUSTERS	
COMPANY	TRADE NAME	COMPANY	TRADE NAME
Amgen & <i>Wyeth</i>	Enbrel	<i>Baxter</i>	Advate
Genentech	Avastin	Amgen	Aranesp
Biogen Idec	Avonex	<i>Eli Lilly</i>	Humalog
<i>Bayer</i> (Schering AG)	Betaseron/Betaferon	<i>Abbott</i>	Humira
Allergan	Botox	<i>Eli Lilly</i>	Humulin
Genzyme	Ceredase/Cerezyme	<i>Sanofi-Aventis</i>	Lantus
<i>Sanofi-Aventis/Teva</i>	Copaxone	Genentech (<i>Roche</i>)/Novartis	Lucentis
Amgen	Epogen	Genentech/ <i>Roche</i> / <i>Chugai</i>	NeoRecormon/Epogin
<i>Merck-Serono/Bristol-Myers/Eli Lilly</i> (ImClone)	Erbitux	Amgen	Neulasta
<i>Novartis</i>	Gleevec	<i>Wyeth</i>	Prevnar
Genentech/ <i>Roche</i>	Herceptin	<i>Abbott</i> /MedImmune	Synagis
<i>Bayer</i>		Kogenate	
Amgen		Neupogen	
<i>Novo-Nordisk</i>		NovoSeven	
<i>Roche</i>		Pegasys	
<i>Schering-Plough</i>		PEG-INTRON	
<i>Johnson&Johnson</i> /Ortho Biotech		Procrit/Eporex	
Serono		Rebif	
<i>Johnson&Johnson</i>		Remicade	
Genentech/ <i>Biogen</i> / <i>Roche</i>		Rituxan/MabThera	

Source: Company SEC filings and annual reports

Note: Notes: A blockbuster is defined as \$1 billion in revenues in at least 1 year. Big Pharma in italics.

Table 4 Distributions to shareholders in the forms of stock repurchases and dividends by major US-based pharmaceutical companies, 1997–2009.

	Sales, 2009	Fortune 500 rank	RP/NI	(TD + RP)/NI	RP/R&D	(TD + RP)/R&D
	\$m	2009	1997–2009	1997–2009	1997–2009	1997–2009
Johnson & Johnson	61,897	33	0.38	0.77	0.57	1.16
Pfizer	50,009	40	0.65	1.33	0.67	1.35
Abbott	30,765	75	0.24	0.82	0.33	1.12
Merck	27,428	85	0.35	0.82	0.62	1.49
Eli Lilly	21,836	112	0.02	0.62	0.01	0.56
BMS	21,634	114	0.18	0.62	1.43	5.01
Allergan	4,504	459	0.59	0.81	0.30	0.42

Sources: Compustat database; 2010 SEC 10-K filings; Fortune 500 list ([http://money.cnn.com/magazines/fortune/fortune500/2010/full list/](http://money.cnn.com/magazines/fortune/fortune500/2010/full_list/)).

TD = total (preferred plus common) dividends; RP = stock repurchases; NI = net income after taxes, before extraordinary items; R&D = research and development.

Table 5 Distributions to shareholders in the forms of stock repurchases and dividends, leading dedicated biopharmaceutical companies, 1997–2009.

	Sales, 2009	Fortune 500 rank	RP/NI	(TD + RP)/NI	RP/R&D	(TD + RP)/R&D
	\$m	2009	1997–2009	1997–2009	1997–2009	1997–2009
Amgen	14,642	159	1.07	1.07	0.99	0.99
Gilead Sciences Genzyme	7,011	324	0.65	0.65	0.58	0.59
Biogen Idec	4,516	458	0.32	0.32	0.11	0.11
	4,377	471	2.05	2.06	0.81	0.81

Sources: Compustat database; SEC 10-K data base; 2010 Fortune 500 list

([http://money.cnn.com/magazines/fortune/fortune500/2010/full list/](http://money.cnn.com/magazines/fortune/fortune500/2010/full_list/)).

For definition of acronyms, see Table 4.

Notes: Biogen Idec includes only Biogen repurchases and R&D before the 2003 merger of the two companies.

Table 6. Gains from the exercise of stock options, average for CEO and other four highest paid executives, 1995-2009 (in US dollars)

	AMGEN	GENENTECH	GILEAD SCIENCES	GENZYME	BIOGEN IDEC
1995	6,817,627	825,701	*	465,309	2,464,961
1996	5,279,364	\$325,679	411,250	721,100	298,066
1997	3,010,156	0	832,369	\$44,373	4,293,557
1998	11,307,884	\$592,149	491,235	1,471,548	615,541
1999	13,330,697	10,763,997	633,146	4,652,625	8,132,058
2000	42,131,827	23,414,861	2,227,746	1,846,424	9,070,194
2001	4,321,772	371,803	4,747,643	5,344,364	1,841,877
2002	2,951,349	0	2,530,736	0	736,089
2003	2,787,683	14,253,173	6,437,089	4,897,291	1,848,609
2004	1,729,808	24,175,200	7,563,908	2,116,807	14,221,925
2005	9,444,582	31,149,362	9,535,369	10,662,508	2,378,898
2006	1,036,550	4,445,274	13,967,766	0	1,695,916
2007	149,045	5,909,682	14,218,719	4,722,735	3,247,255
2008	1,190,447	**	767,552	2,057,562	4,235,246
2009	253,620	**	19,820,513	2,679,877	5,946
1995-2007		\$116,226,881			
1996-2009			\$84,185,041		
1995-2009	\$105,742,411			\$41,682,523	\$55,086,138

* Gilead Sciences did not report these data for fiscal 1995.

** In 2009 Genentech was acquired by Roche and did not release these data for 2008

Sources: SEC filings and Compustat database

Appendix: Figures 1-9

Figure 1. Venture-backed deals and venture-capital investments (if known) (in 2009 dollars) in US biotechnology, 1978-2009

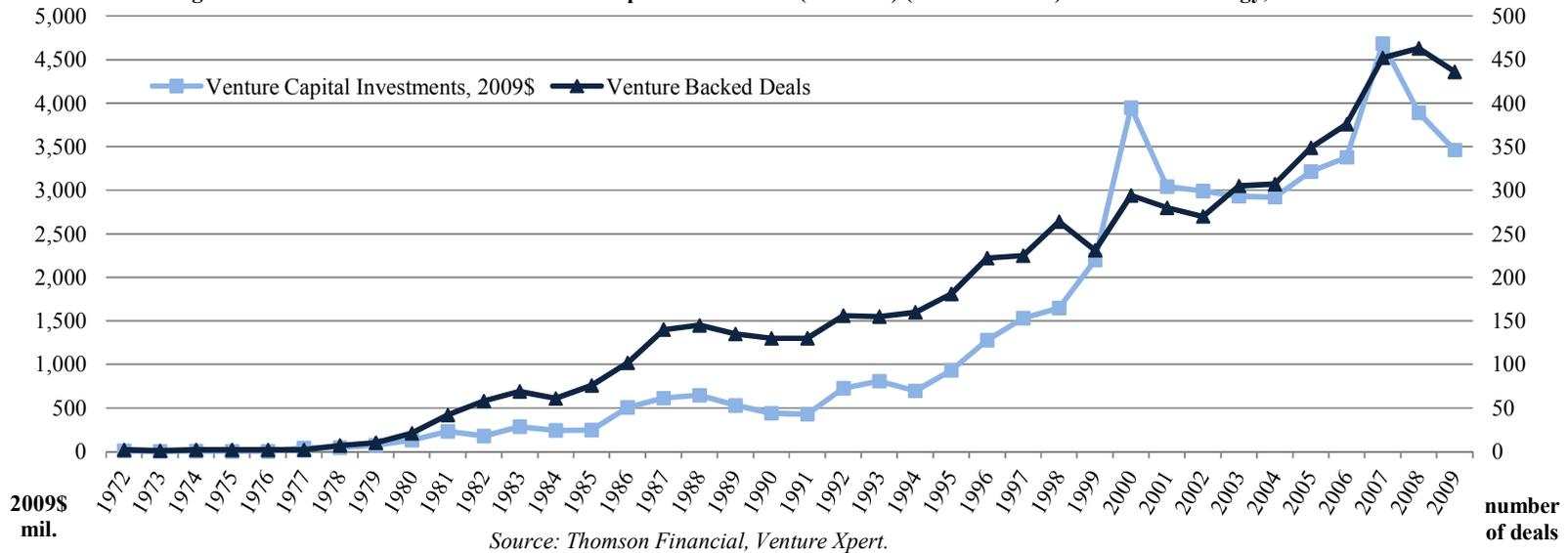
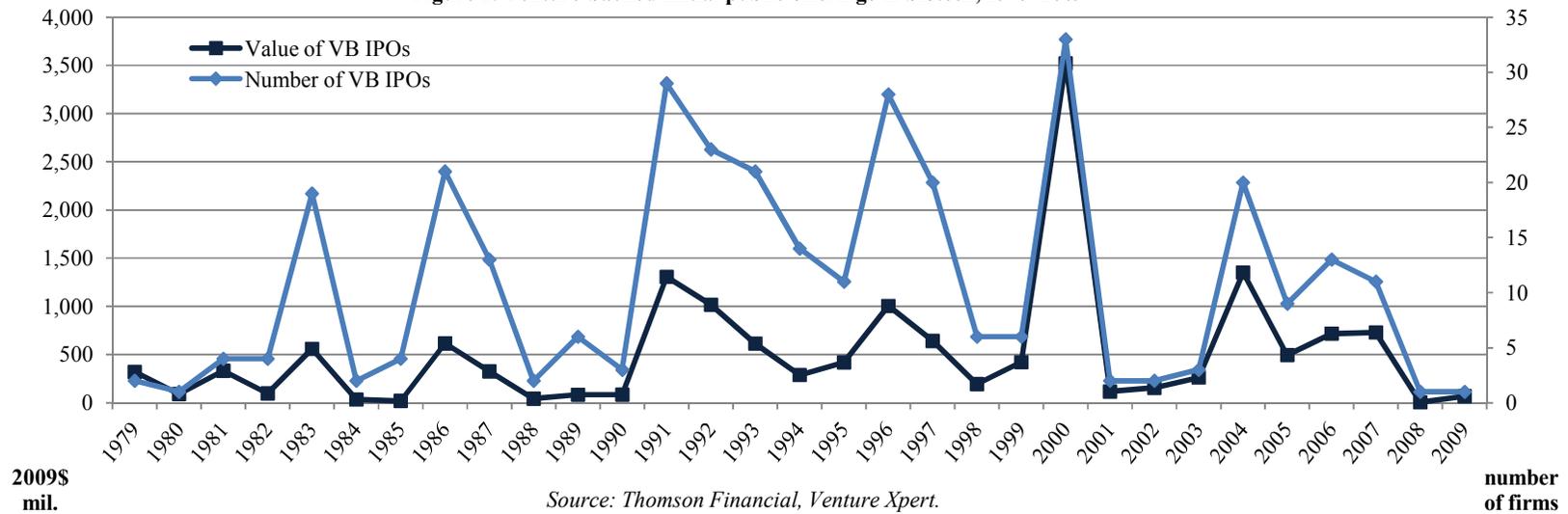


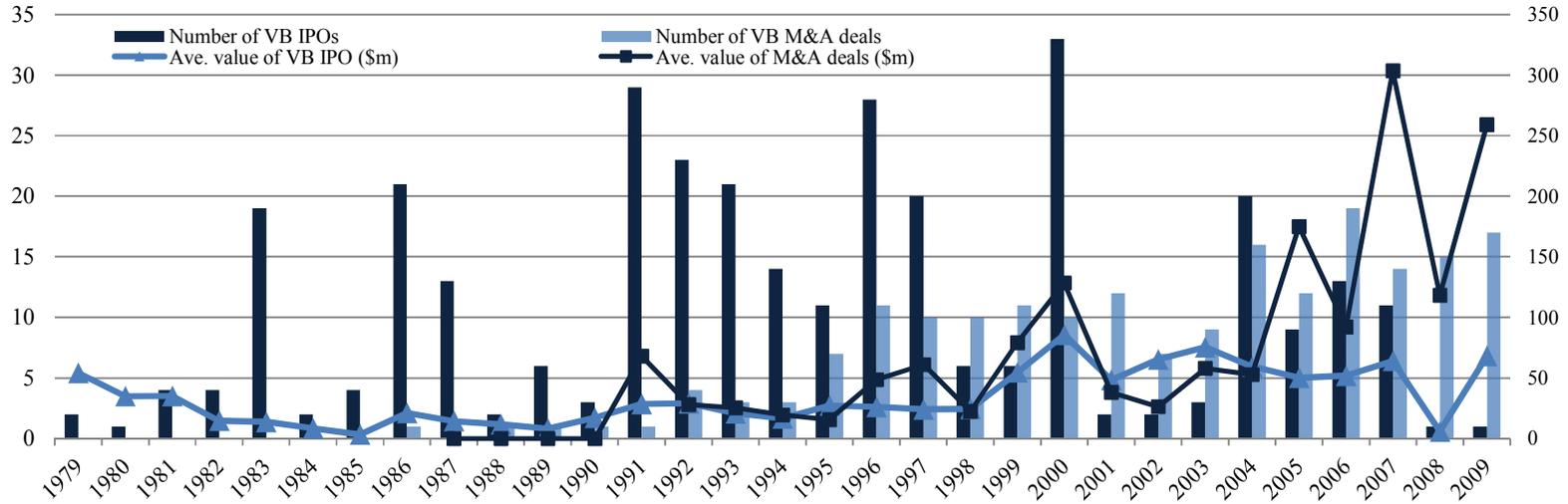
Figure 2. Venture-backed initial public offerings in biotech, 1979-2009



Number of Deals

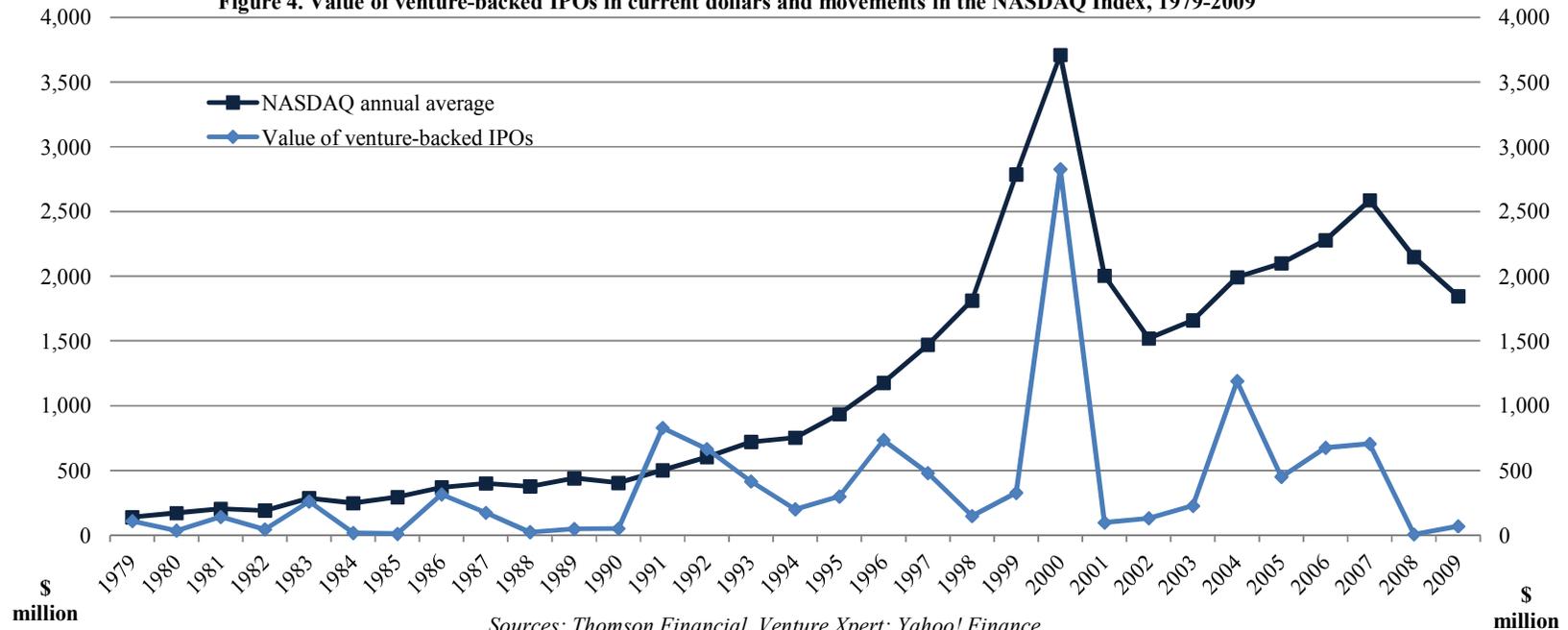
Figure 3. Number and value of IPOs and M&A deals in biotechnology, 1979-2009

Average Value of Deals (if known) (\$m)



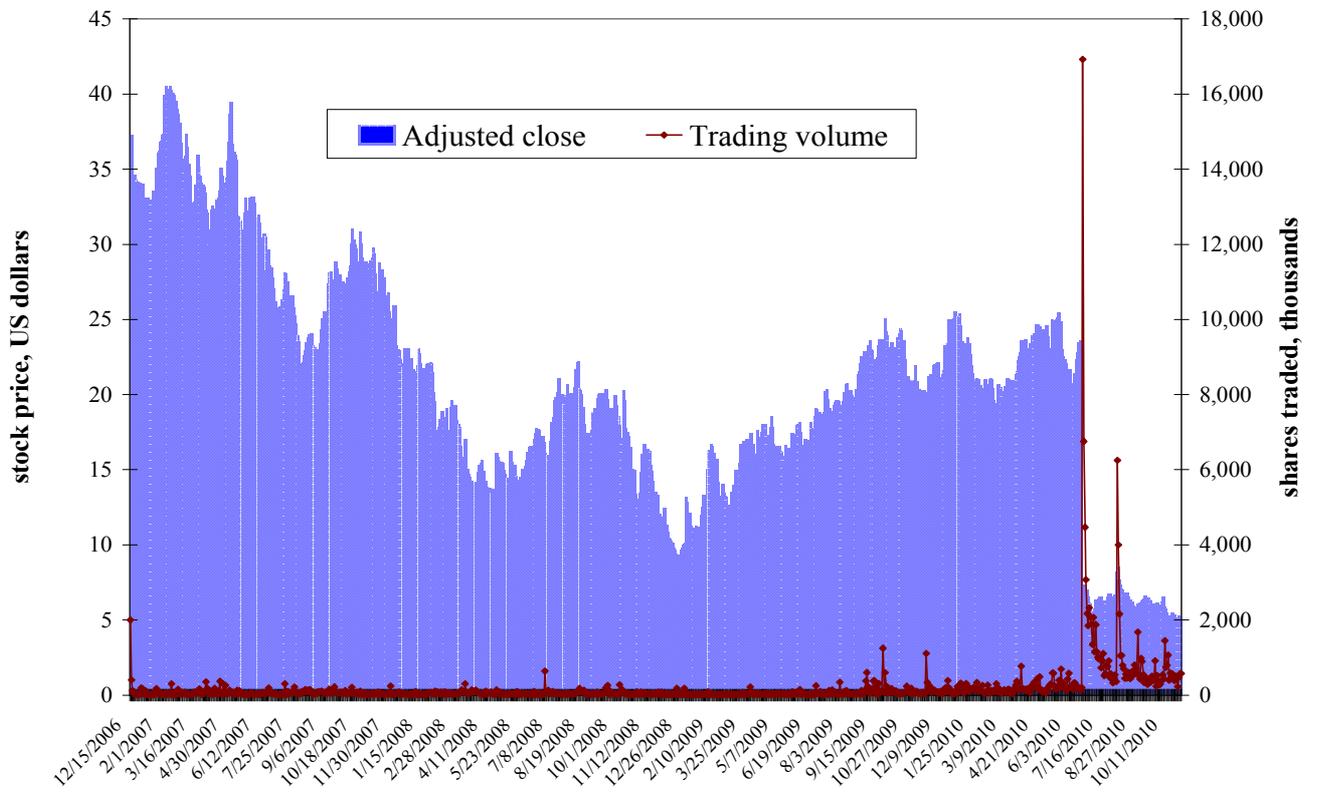
Source: Thomson Financial, Venture Xpert.

Figure 4. Value of venture-backed IPOs in current dollars and movements in the NASDAQ Index, 1979-2009



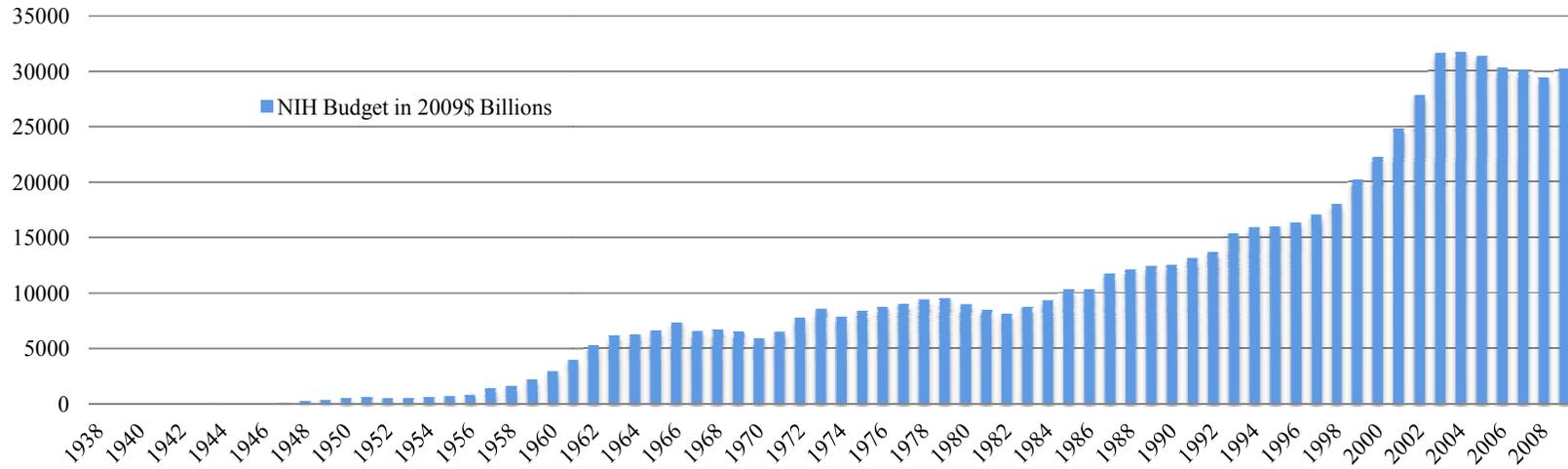
Sources: Thomson Financial, Venture Xpert; Yahoo! Finance.

Figure 5. Stock-price movements and trading volume of Affymax shares, December 2006-October 2010



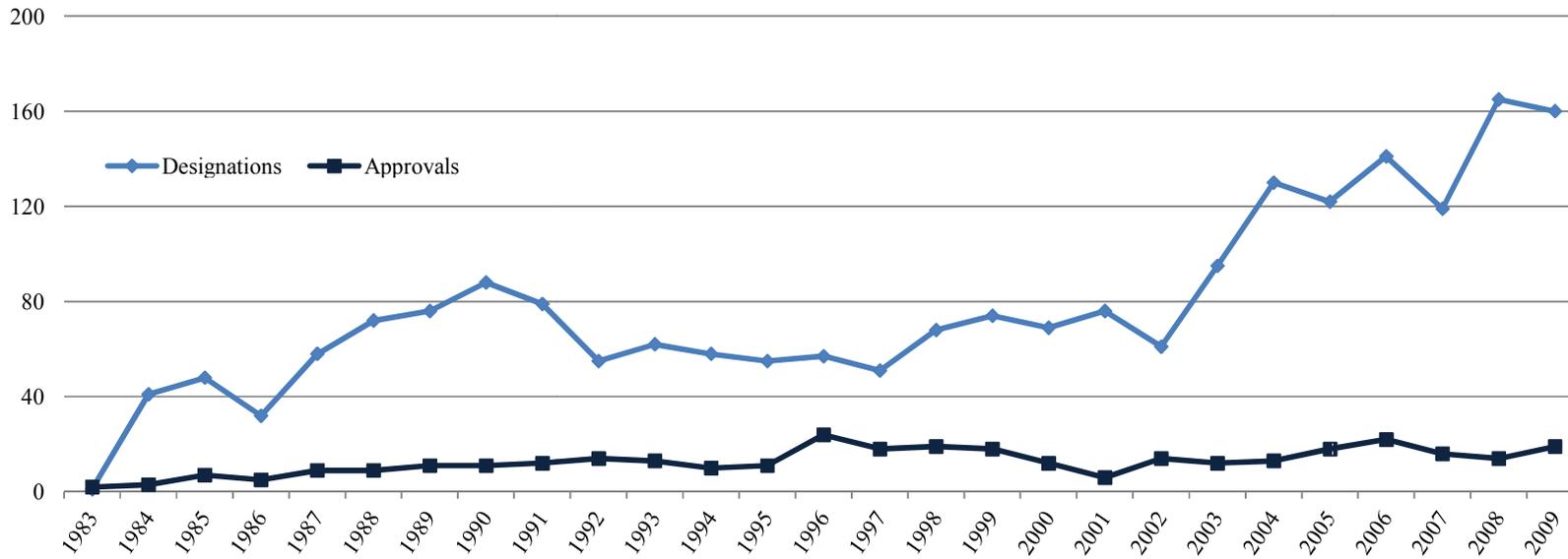
Source: Yahoo! Finance.

Figure 6. National Institutes of Health funding, 1938-2009, in 2009 dollars



Source: National Institutes of Health, 2009

Figure 7: Number of orphan drug designations and approvals per year, 1983-2009



Source: Food and Drug Administration, 2009

Figure 8a. Blockbuster biopharmaceutical orphan drugs, 1992-2009

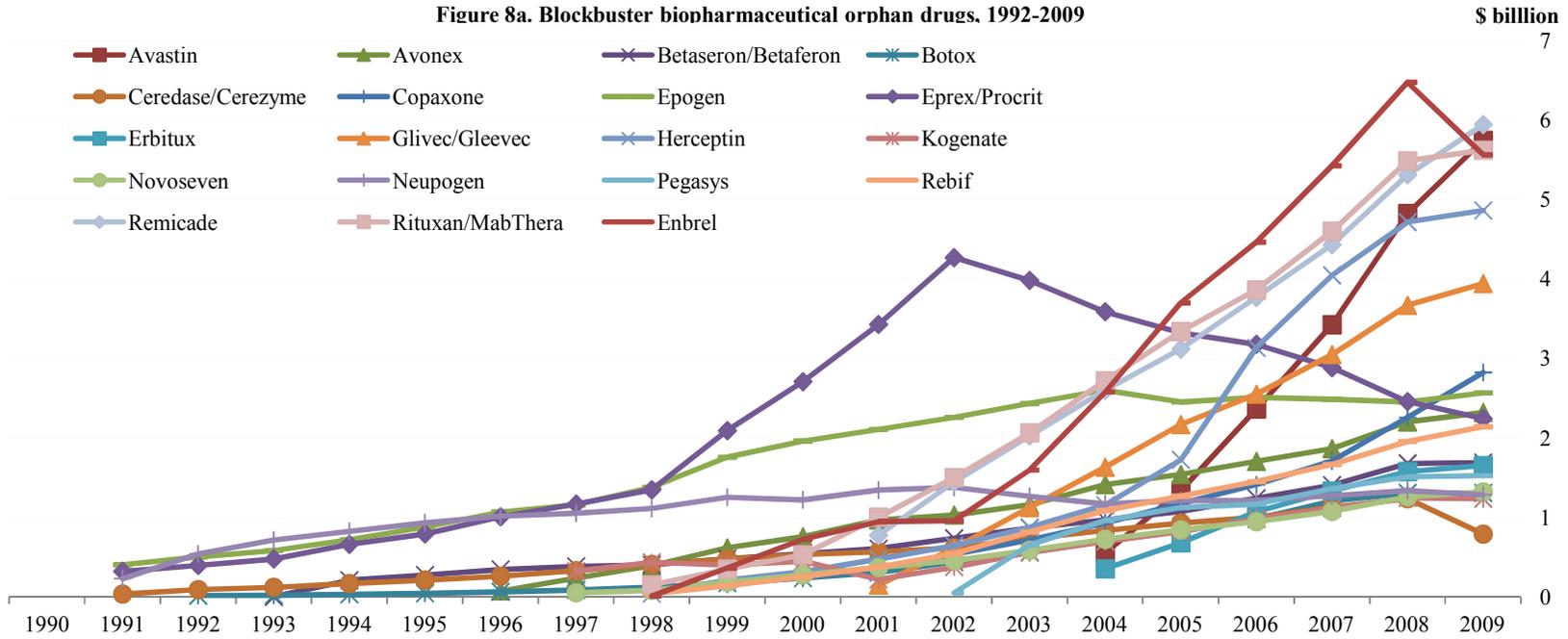
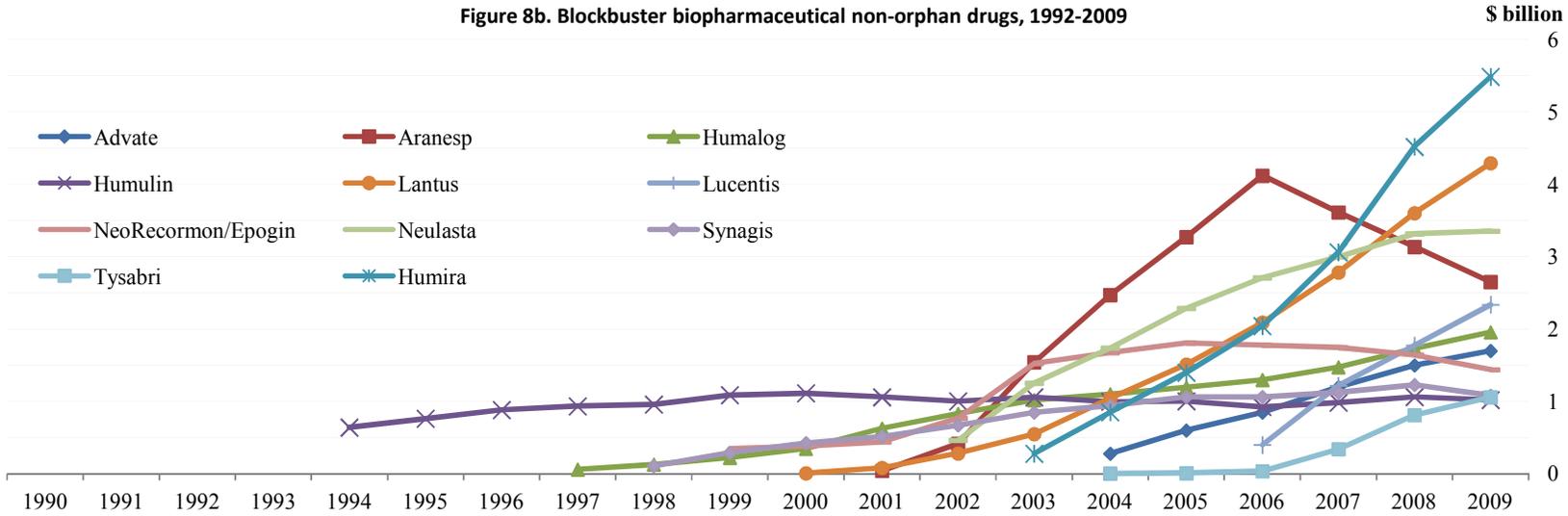


Figure 8b. Blockbuster biopharmaceutical non-orphan drugs, 1992-2009



Source: Company SEC filings and annual reports.

Figure 9. The US biopharmaceutical funding structure

