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Cephalon, Inc. Taking Risk Management Theory Seriously
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ABSTRACT

We study a firm that justifies its novel use of equity derivatives as a cash-flow hedging strategy. Our purpose is to understand the challenge of translating risk management theory into managerial action. Cephalon Inc., a biotech firm, bought a large block of call options on its own stock. If the FDA approved the firm's new drug, the firm would have large cash needs, which the options were designed to meet. We analyze this stated rationale for the firm's choice, applying the cash flow hedging concepts articulated by Froot, Scharfstein and Stein (1993). In applying the theory to practice, there are lessons for both managers and theorists. Managers consider deadweight costs *of financing* and of risk management, whereas theory tends to ignore the latter costs. While theory is driven by costs of external financing, managers must measure these costs to arrive at decisions and this measurement problem is severe. Cephalon's risk management decisions seem motivated as much by fluctuations in the availability and cost of external financing and by accounting considerations as by fluctuations in operating cash flows or desired investment. Finally, even a field-based examination of this strategy cannot reject the conclusion that the transaction was motivated by goals other than risk management.

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I. Introduction

Even though the theory of corporate risk management has advanced over the years, applying these principles in businesses can be exceedingly difficult. This paper documents an unusual derivatives transaction that was ostensibly motivated by risk management considerations. We work through the analyses that would justify this decision, not so much as to judge the wisdom of the particular transaction, as to demonstrate the link between risk management theory and practice. Our analysis not only highlights the complications managers face when applying stylized risk management theory, but also demonstrates the richness of practice that is sometimes ignored by theory.

The business situation we describe was that faced by Cephalon, Inc., a biotechnology firm. In early 1997, Cephalon implemented a derivatives transaction that confused many observers: it bought 2.5 million call options on its own stock by issuing about one-fifth as many shares of common stock to SBC Warburg, the writer of the calls. Cephalon's first major drug (Myotrophin) would soon either be approved or disapproved by the U.S. Food and Drug Administration (FDA), and Cephalon argued that it would need to raise large sums of cash if the drug were approved. This cash was needed to make a very attractive investment: the repurchase of the legal rights to Myotrophin, which it had sold to investors in an R&D limited partnership. The firm's internally-generated cash would be insufficient to make this payment. The managers reasoned that if the FDA were to approve the drug, the firm's stock would rise in value to reflect the future value of the drug, its purchased call options would pay off, and the firm could use these proceeds to finance part of its needs. The managers viewed the call options as an integral part of the firm's risk management strategy.

The firm's stated rationale for the transaction is closely related to the notion of cash-flow hedging, as most recently articulated by Froot, Scharfstein and Stein (or FSS 1993, 1994). In this theory, firms engineer their internal cash flows to meet their investment needs in order to avoid either deadweight costs of external financing or suboptimal investment policy.

Even though the theoretical rationale for this type of risk management is well understood, applying it at Cephalon raises a number of issues that may help us to direct empirical research, understand corporate decision-making, and sharpen risk management theory:

- Risk management choices are made in a rich corporate context. Here, accounting rules (and managers' interpretation of their impact on firm value) have a critical effect on the firm's risk management choices. In this case, the rationale for risk management seems as much motivated by managing earnings as by managing cash flows.

- Risk management is usually motivated by the presence of deadweight costs, either of financing or financial distress. However, if managing risk itself also entails deadweight costs, then firms must compare *relative* deadweight costs. Our analysis suggests that they may be large when equity derivatives are used to manage risk.

- Academic models of risk management require managers to measure the size of these deadweight costs, but provide little guidance about how to calculate these costs. We found little reliable data that a manager could use to benchmark the costs of external financing. As an empirical matter, in this case, deadweight costs of financing may be quite small or possibly even negative.

- Risk management decisions seem motivated as much by fluctuations in the cost and availability of financing as by fluctuations in either operating cash flows or desired investment.

- While firms can hedge market-wide risks, they are often unable to protect against purely idiosyncratic business risks except by using insurance. This clinical study documents a firm using the capital markets to manage a combination of an idiosyncratic risk and financing uncertainty.

- Finally, even in this clinical study, where management was quite clear in its explanation of its objectives, one cannot reject an alternative explanation that the transaction simply allowed the firm to bet on the success of its drug.

We have two goals in documenting this transaction. First, we seek to communicate to academics the richness of practice that is often ignored in abstract risk-management theory. We do so to encourage natural extensions to existing theory, such as acknowledging potential deadweight costs of managing risk. Second, we hope to highlight for managers analyses that could be used to approach risk management decisions, such as alternative ways to measure the deadweight costs of financing. In general, our goal is to help build a bridge between abstract risk management theory and its concrete use by firms.

We provide readers with details on the company's risk management problem (in section II of the paper), briefly summarize the theory of cash-flow hedging (section III), and describe the relationship between these two (section IV). We also value the options purchased by Cephalon in section V to determine the deadweight costs of the risk management strategy. A separate Appendix (available from the authors) details the technical treatment of this valuation, which is complicated by the fact that the options are essentially "negative warrants" and the price dynamics of the underlying stock include a material jump (the FDA panel recommendation). Finally, we report on the market's reaction to Cephalon's decision (section VI). We conclude by suggesting lessons that academics and managers might learn from Cephalon's experience (section VII).

II. The business environment and decisions facing Cephalon[1]

Cephalon's decision to buy options as a risk management strategy must be understood in the context of its business. This section briefly describes three elements of the business environment, including (1) the importance of the imminent FDA panel decision to Cephalon; (2) the decisions that Cephalon would face if the panel were to approve the drug; and (3) the terms of the option proposal.

The imminent FDA decision: Founded in 1987, Cephalon, Inc. is a biotechnology firm that focuses on treatments for neurological disorders. In spring 1997, while the company had neither FDA-approved drugs nor commercial sales, it anticipated imminent FDA review and subsequent commercialization of its first drug, Myotrophin, a treatment for Amytrophic Lateral Sclerosis (ALS). ALS, or Lou Gehrig's disease, is a fatal neurodegenerative disorder characterized by the deterioration of sensory and motor nerves. The disease's cause is unknown and there is no known

[1] For more details, see the Harvard Business School case study by Tufano, Mullarkey and Verter, "*Cephalon, Inc." (298-116).*

cure. Analysts estimate that ALS afflicts approximately 75,000 people worldwide and that the worldwide market for treatments could generate revenues of $500 million annually.[2]

Cephalon developed Myotrophin in partnership with Chiron Corporation, a California-based biotechnology firm, at a cost reported to be approximately $180 million.[3] Preliminary scientific studies suggested the drug had potential to slow the onset of the physical decline accompanying ALS. However, before it could sell Myotrophin commercially, Cephalon was required to conduct a series of company-sponsored clinical tests and pass formal FDA regulatory reviews.[4] Cephalon was nearing the end of this series of steps in 1997. In 1995, it had released the results of its first combined Phase II/III clinical trial, the "North American trial." The trial showed statistically significant results indicating that Myotrophin slowed the progression of ALS and that side effects were minor. Later that year, the company announced the results of a second trial, the "European trial." The results of this trial were less compelling than those of the North American study. On the basis of these two studies, the company filed an application to expand patient access to the drug prior to FDA approval.

On February 11, 1997, Cephalon submitted a New Drug Application (NDA) for Myotrophin. An advisory panel meeting was scheduled for May 8, 1997. Most observers felt the panel's approval was highly likely, with two analysts stating that the probability of approval was as high as 70%.[5] Others privately expressed the approval probability at 80% or better.

If approved, Myotrophin would be an important source of revenue for Cephalon. Equity analysts' projections of Myotrophin annual sales ranged from $30 million in 1997 to over $400

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[2] See Lonergan, Stone, and Reed (February 20, 1997) and Malloy (March 20, 1997). The market potential for addressing the broader class of medical disorders was estimated at over $3 billion.

[3] Cephalon conducted the majority of the preliminary research and clinical testing, and Chiron would be responsible for manufacturing Myotrophin, were the drug be approved. Development costs were split evenly between the companies, and production costs and commercial sales would be divided evenly as well. Cephalon reported to us that its partnership with Chiron had no material impact on Cephalon's financing choices or on the decision to purchase the options.

[4] See Shane (1995) and Cephalon, Inc.'s December 1996 10-K filing for more detail on the FDA approval process.

[5] See Wilson and Schmidt (May 7, 1997) and Bishop (1997).

million in 1999. Analysts predicted that Cephalon's stock (which was trading for about $20 in early April 1997) would be worth $30-$40 per share if Myotrophin were approved, but if disapproved, only $10-$15 per share. The approval would not generate immediate cash flow for Cephalon, as development would take a few years.

Cephalon's decisions if Myotrophin was approved: While the approval of Myotrophin would be good news to Cephalon, it would present management with a series of immediate financial decisions. **Figure 1** illustrates the sequence of decisions. First, management had to decide *whether* to buy back the rights to Myotrophin. As is common in this industry, to fund the drug's development, Cephalon raised $38.7 million in August 1992 from Cephalon Clinical Partners, L.P. (CCP), a research and development limited partnership sold by PaineWebber.[6] The partnership owned the exclusive license for the drug, but it granted Cephalon an interim license to manufacture and market the drug in the U.S., Canada and Europe. For this license, Cephalon would owe CCP a *Milestone Payment* payable when the drug received regulatory approval. Unless Cephalon subsequently bought back the rights to the drug, it would lose the future expected cash flows from the sales of Myotrophin after this interim period.

Second, the managers had to decide *how* to buy back the rights to drug, if it was approved. Under the limited partnership agreement, Cephalon had the right, but not the obligation, to buy back the rights to the drug by making a *contractual Purchase Option Payment* of about $40 million two years after the first commercial sale and by paying royalties to the CCP partners for another eleven years. Cephalon would also need to pay the $16 million Milestone Payment under this arrangement. Instead of exercising this contractual purchase option, Cephalon could *tender* for the CCP interests directly, which managers estimated might cost the firm $125 million in cash, including the Milestone Payment. As we discuss later, Cephalon could make these payments in either cash or

[6] For a discussion of this means of financing R&D, see Beatty, Berger, and Magliolo (1995).

Cephalon stock. In addition to the needs to buy back the drug, the firm might require $20 million or more to complete development of the drug.

Third, if Cephalon sought to buy back the interests with cash (especially in a tender), it would need to identify *sources and timing of additional funds*. Managers felt fairly confident that they could raise $80 to $100 million through security offerings in the few years after the FDA decision, but felt that it would be difficult to raise any additional funds. It was this incremental funding need that the option proposal was designed to meet.

The option proposal: Because Cephalon needed money if the panel approved the drug, the firm needed what Kevin Buchi, the firm's CFO, called a "backwards insurance policy"; i.e., one that paid off if things went well, not poorly. As the company discussed financing with various investment banks at the beginning of 1997, bankers at SBC Warburg (SBC) proposed an innovative financial strategy that offered this insurance. They suggested that Cephalon buy call options on its own stock, so it would benefit from a share price increase that would likely follow FDA approval of Myotrophin. While companies increasingly were transacting in put options on their own stock to enhance share repurchases, the call proposal was quite rare in the corporate sector.[7]

Under the transaction, Cephalon would purchase 2.5 million capped call options from SBC Warburg, in exchange for 490,000 shares of Cephalon common stock. The final terms of the options were set on their date of issue, May 7, the day before the FDA panel meeting. [8] The options were European-style with an expiration date of October 31, 1997. The strike price for the calls was set at $21.50 per share and the cap at $39.50 per share, so that Cephalon's payoff per share was limited to

[7] Derivative-based stock-buybacks are discussed in Innes, Blanton, Nomo-Ongolo, and Sieden (1997) and Browning and Lucchetti (1997). Prior to Cephalon, a few firms had bought calls on their own stock. For example, it has been reported that Cadence Systems bought calls on its stock (and wrote puts) as part of its repurchase strategy (see Barr (1997)).

[8] Cephalon management intended to execute the option purchase in April 1997, but its registration of a convertible issue delayed the filing of the option deal until May 7, 1997, one day before the FDA advisory panel meeting.

$18.[9] In order to decide whether to accept the SBC proposal, Cephalon's managers needed to consider the appropriateness of the transaction as part of their risk management program, and it is this decision that the remainder of this paper analyzes.

III. The Theory of Cash-Flow Hedging

In press statements and SEC filings, Cephalon's executives explained their motivation for the call option transaction. Kevin Buchi, Cephalon's CFO, describes the transaction most succinctly: "It [the call option position] provides us with cash when we need it the most."[10] This argument for the option transaction is a near-textbook application of the theory of cash-flow hedging as recently discussed by Froot, Scharfstein and Stein (FSS 1993, 1994).[11] They argue that "the role of risk management is to ensure that a company has the cash available to make value-enhancing investments." Rather than simply reducing the variability of a firm's earnings or cash flows, the cash-flow hedging theory may lead a firm to *increase* these volatilities. In particular, it has the firm engineer its operating cash flows to match the investment opportunities that it faces. If the firm's best investment opportunities are highly variable, then it is appropriate to have variable operating cash flows. In Cephalon's case, where investment opportunities arise in good times, it can be

[9] The options were Asian-style in that the final stock price used in the calculations was the average of Cephalon's NASDAQ share price, observed three times each day (at 10:00 am, 12:00 p.m. and 3:00 p.m., EST) over the twenty trading days preceding and including October 31. At maturity, Cephalon could either receive cash from SBC if the options were in the money or it could pay the exercise price and receive shares. Cephalon anticipated using cash settlement if the options were in-the-money. The stock-settlement clause permitted Cephalon to account for the option gains as part of comprehensive income and not on the income statement. The CFO explained that this clause did not cost Cephalon in terms of effective premium paid, but gave the firm a more attractive accounting treatment.

[10] Quoted in Ward (1997).

[11] The general notion that capital market imperfections could lead to optimal risk management had been advanced earlier in a number of papers including Stulz (1990) and Lessard (1990). There are a number of theories of risk management, whereby corporate risk management is the outcome of non-linear tax schedules, costs of financial distress, managerial risk aversion, or imperfect information. For discussions of these alternative explanations of risk management, see Stulz (1984, 1990, 1996), Smith and Stulz (1985), or DeMarzo and Duffie (1995), among others.

optimal for the risk management program to strengthen already-strong cash flows in these periods.

Under the theory, as articulated by FSS, firms face risky positive-NPV investment opportunities. A key assumption of the model is that firms incur deadweight costs when raising external finance, and this cost is increasing in the amount raised. These deadweight costs justify hedging because they lead firms to underinvest relative to the first-best solution, linking their investment activities to their internally-available cash flow.[12] Theory does not suggest how to measure these deadweight costs.

Mapping this framework to Cephalon's case is straightforward, although then determining whether the company's transaction is justified on risk management grounds is not, as we discuss subsequently. The exogenous risk factor is the FDA approval, an idiosyncratic risk. This risk factor may affect operating cash flows, the optimal investment levels, or the costs of external financing. For cash flow hedging of this risk to be justified, the theory suggests that managers need to ascertain the following:

1. *Investment attractiveness:* In the event that Myotrophin is approved, the firm will have a valuable investment opportunity in buying back the rights to the drug .

2. *Investment needs and internal resources*: Cephalon's internal cash flow is insufficient to meet these needs.

3. *Costs of external finance*: High (and convex) costs of external financing make financing this need externally sub-optimal, and could lead to a second-best investment decision. One must explicitly consider the effect of the risk factor (the FDA approval) on the cost of financing.

4. *Appropriateness of risk management program*: The option will provide the proper payoff when the firm needs the cash. Specifically, if the FDA approves Myotrophin, the firm's stock will rise and the option will pay off. While theory assumes that risk management is costless (with respect to deadweight costs), if this were not the case, we would need to determine that the option is a cost-effective way of raising the needed funds.

[12] Some empirical evidence supports this general proposition. For example, see Fazarri, Hubbard and Peterson (1988). Lamont (1997) also finds that investment is sensitive to cash flow, but he suggests that a decrease in cash flow may lead to more efficient investment if diversified firms overinvest when cash flow is high.

IV. Applying the cash-flow hedging arguments in practice

In this section, we review the four contentions introduced in the prior section. Our goal is to specify the data and analyses required to justify the option purchase decision under the theory of cash-flow hedging.

Contention 1: If the FDA approves Myotrophin, Cephalon will have an attractive investment opportunity—buying back the rights to the drug. In applying the cash-flow hedging argument, the first step is show that the repurchase of the rights to Myotrophin enhances shareholder value. If not, risk management could be misused to destroy shareholder value by eliminating valuable capital markets discipline (Tufano (1998)).

In **Table 1,** we analyze the financial implications of the buyback, using a composite of analysts' estimates of Myotrophin sales and profits and a discounted cash flow approach. The internal rate of return of buying back the approved drug ranges from 81% to 266%, depending on whether Cephalon uses a tender offer or the purchase option to buy back the rights. Either of these is well above the 25% hurdle rate used by equity analysts studying Cephalon. The buyback has an NPV of $340 to $408 million (even excluding a terminal value) and is an attractive investment, regardless of the method of purchase.[13]

Cephalon could either buy back the rights through a tender offer or through the contractual purchase option. Given the *pro forma* projections, the two offers have equal value using a 40% discount rate (or at a 25% discount rate, if revenues are half as large as shown).[14] This rough comparability makes economic sense: were Cephalon to offer the limited partners an inferior tender

[13] With a zero growth rate and a 25% discount rate, valuing the terminal value as a perpetuity might add $25 million to the NPV calculation. This analysis ignores any follow-on business opportunities, which would be best modeled using a real options approach.

[14] The $125 million value for the tender offer was apparently determined through negotiations with representatives of the limited partners, and was believed to be an good estimate of the tender. These analyses assume that the purchase price is paid in cash, although Cephalon had the right to pay the purchase option price in stock. This alternative is discussed later. Tax implications of the buyback are not taken into account in the analysis.

offer, they would reject it, but Cephalon would not have a strong incentive to offer a much better deal than they could obtain through the contractual purchase option contract terms.[15]

Contention 2: Cephalon's internal cash flow is inadequate to fund this investment. If Cephalon's internal cash flow were sufficient to fund the valuable investment opportunity, there would be no reason to devise a complicated cash-flow hedging scheme.[16] Cephalon's managers justified the option purchase on the argument that in the event of FDA approval, the firm's internal cash flow would be insufficient to fund on-going business activities as well as repurchase the rights to Myotrophin. [17] To the contrary, our analysis suggests that Cephalon probably could have funded a cash buyback *without* the proposed hedging strategy, and the cash-flow shortfall was the result of the firm's insistence on using one particular way to buy back the rights.

Because Cephalon does not provide projections of its future needs, we use analysts' forecasts to estimate these needs. **Table 2** summarizes projections for future cash flow needs for 1997 through 1999, if Myotrophin was approved and if Cephalon bought the CCP interests with *cash*, either through a tender or the contractual purchase option. Even if Myotrophin had been approved, Cephalon would continue to experience negative operating and investment cash flows for a few years, as sales would not ramp-up immediately. Were it to buy out the partnership for $125 million in cash in 1997, the firm would face a total financing shortfall of about $200 million in that year or $230 million over the next two years. Were it to exercise the purchase option and make the $40 million payment to CCP in 1999, it would face a shortfall of $85 million in 1997 and $129 over the two-year period, roughly half of the shortfall a cash tender would create.

These figures must be evaluated in light of three factors: (a) the firm's December 1996 cash

[15] The *ex post* attractiveness of the buyout to Cephalon does not necessarily indicate that the limited partnership was mispriced *ex ante*, a topic that is beyond the scope of this paper.
[16] In this section we discuss only cash-based investment alternatives. We defer the discussion of the equity alternatives to the next section.
[17] See Cephalon's May 5, 1997 8-K, p. 7.

balances of $146 million, (b) its goal to maintain target cash balances equal to a few years of operating expenses, and (c) its expectation that it could raise $100 million through a combination of offerings similar to a privately-placed convertible offering that closed on May 7, 1997. In view of these constraints and resources, the firm could probably meet the near-term cash-flow requirements of the *purchase option alternative* without resorting to the option purchase proposal. However, it could not carry out the *cash tender offer* without almost completely depleting its cash balances by the end of 1998. Hence, if the firm were indifferent about the means of buying back the CCP rights, the risk management problem would have been less severe.

Even though the contractual purchase option produces a more manageable cash flow strain on Cephalon and an NPV comparable to that of the tender, virtually all of the discussion by Cephalon and analysts focused on the cash tender offer as the means of buying back the Myotrophin rights. At first, we suspected that this preference was the result of management's belief that Myotrophin sales might far exceed even the projections we used, or due to tax considerations. Through discussions with company management, we discovered that the accounting treatment best explained their preference.

If the firm were to make a cash tender for the limited partnership interests after the panel approval but before the full FDA approval, it could expense the entire amount as purchased in-process research and development, because the final outcome would be deemed to be uncertain. This would give rise to large expense for both accounting and tax purposes in the current year—in which it would have negative earnings anyway—but lower expenses and higher earnings in future years when it would be making positive earnings.[18]

However, if the firm were to exercise the purchase option instead of the tender, it would buy back the rights to Myotrophin *after* the final FDA approval. Under GAAP, Cephalon would

[18] The cash tender would also generate an immediate net operating loss (NOL) that the firm could use as Myotrophin earnings materialized, but given that the firm already had $75 million in NOLs and would generate them for a few more years, accelerating them would add little practical value.

need to capitalize the purchased research and development for Myotrophin and expense it over the life of the drug.[19] This would spread out the buyback expense for both accounting and tax reporting and lead to lower earnings over the drug's life. Thus, Cephalon could either take a big loss in the current year, or spread the cost of the buyback over the next decade.

Research has shown that firms engage in "big baths" typically around management turnover, or in instances where executive compensation plans are keyed to earnings (Healey (1985)). Neither of these circumstances seem at play in this case; management had not recently changed, nor were their earnings-based compensation programs for top managers. Rather, the rationale flows from the strongly held management belief that the immediate recognition of losses while the firm was still in the development phase would lead to higher ultimate market value than would the depression of accounting earnings over the life of Myotrophin. Thus management's belief about the way in which analysts relate earnings to firm value is central to its risk management choice. As explained to us, "It is interesting that all the models used by analysts to value [Cephalon] stock take a discounted P/E approach. This transaction (the tender offer) materially affects this form of valuation."

While there is general academic evidence that accounting choices affect valuation,[20] it is harder to judge whether Cephalon managers' specific accounting concerns are relevant. At this point, the value—and limit—of clinical research becomes apparent. Its value is to show the role that this belief plays in explaining the firm's risk management choices and to highlight this topic as an important one for future theoretical and empirical research. The limitation of clinical research is that it cannot help us to understand whether management's proposition is correct.

Apart from these accounting considerations, the analysis reminds us that a firm's optimal

[19] A portion of the R&D for non-ALS uses of Myotrophin might be able to expensed even after the FDA approval for the drug's use in the treatment of ALS. This accounting treatment was promulgated in GAAP statements FAS-2 and FIN-4.

[20] See, for example, Moses (1987), Ronen and Sadan (1975), Lang (1991), and Barth, Elliot and Finn (1995).

cash balance, as well as its expected ability to raise financing in the future, interact to influence firms' risk management programs.[21] We were told that it is common practice in the biotechnology industry for firms to carry large cash balances, in essence pre-funding themselves or providing a form of risk management.[22] Partly in jest, we were informed that, "No biotech firm ever went out of business because they had too much cash." Cephalon sought to keep cash balances on hand equal to two to three years of projected spending because of the belief that markets can be uncertain, and that their ability to raise cash could not be assured. Opler et al. (1999) document that this type of precautionary motive for holding cash is widespread, with the mean (median) Compustat firm holding cash equal to about two (one) years of capital expenditures. Thus, a risk management decision—especially one driven by cash-flow concerns—must be determined in conjunction with its policy regarding target cash balances, and both are affected by expectations of future funding ability.

Contention 3: Funding this need externally is unattractive. The core assumption behind cash flow hedging is that external financing is unavailable or very costly. If financing was not costly or if the costs of financing were not convex, cash flow hedging would not make sense. Also, the theory contemplates that the cost of financing could fluctuate with the uncertain risk factor. While one can accept the general contention that external financing is costly, to implement the theory, we need to measure these costs, especially financing costs that relate to the key risk factor—the FDA decision.[23] Our analysis suggests that external financing might not be so costly to

[21] Cash holding decisions by corporations are discussed in Opler, Pinkowitz, Stulz and Williamson (1999). A desire to hold liquidity also forms the basis of Holmstrom and Tirole's (1999) liquidity-based asset pricing model.

[22] Tufano (1996) finds an inverse relationship between cash balances and risk management activity in the gold mining industry, although Opler et al. (1999) fail to demonstrate this relationship.

[23] The fixed-scale of Cephalon's investment introduces a complication that FSS specifically consider. With a fixed-scale investment, hedging is optimal only if this deadweight cost function is convex, so the formal application of the model requires not only that Cephalon's managers recognize the existence of deadweight costs, but also that the first and second derivatives of these costs meet the conditions described above.

Cephalon, especially if Myotrophin were approved, so as to justify its risk management choice.

Deadweight costs of external finance may arise from a variety of causes. Informational asymmetries are thought to be determinants of the high cost of issuing equity and used to explain the empirical regularity that equity issues tend to depress stock prices.[24] But how costly is external financing and how do we measure these costs? As a first step, we asked the firm's CFO to identify the costs of raising funds. He suggested that these costs included underwriting fees, expenses, underpricing and market impact, and estimated that the total costs of raising equity range between 16% and 20%, and slightly less for equity-linked debt or R&D limited partnerships. Academic readers of this paper have questioned how a manager would arrive at this estimate, but the question itself reveals that neither managers nor academics have developed a standard approach to estimating these costs.

Event study reactions to security offerings are sometimes used as evidence of the magnitude of information asymmetries and the costs associated with these asymmetries. For example, Froot et al. (1993) cite the 3% drop in market value upon the announcement of equity issues in discussing information asymmetries that make equity financing costly.[25] In **Table 3,** we examine the extent to which the firm's announcements of previous external financings have affected the value of the firm's equity to crudely gauge the size of external financing costs. On average, Cephalon's three equity offerings depressed the market value of the firm about 6.0% each, for an average offering dilution of nearly 30% of the amount raised.[26]

However, each of these offerings was done prior to the FDA decision, arguably when information asymmetries and therefore costs of external financing were high. We suspect that the informational impact of a post-FDA financing should be much smaller, and perhaps not even

[24] See Froot et al. (1993), pp. 1633-1634 for a discussion. Myers and Majluf (1984) provide an early discussion of the costs of external financing and their impact on firm investment decisions.
[25] For a summary of these results, see Smith (1987).
[26] In contrast, the announcement of the private placement of a convertible debt issue was greeted with a *positive* abnormal return of 8.1% and substantial *positive* offering dilution.

negative. The firm's funding need would be well-known, given its pre-announced need for funds. It would follow the revelation of validated and material information, and under these circumstances informational asymmetries and costs of external financing should decline. Korajczyk, Lucas and McDonald (1991) find that the decline stocks typically experience after an announcement of a new issue is smallest when credible information has just been released, as this is when information asymmetries are the lowest. Consequently, if Cephalon were to raise equity right after the release of verified, credible "*good* news," the FDA decision, we might expect a small signaling penalty, if any at all.

To begin to explore this hypothesis, we examined Shane's (1995) sample of biotechnology firms whose therapeutic products were reviewed by the FDA in the period 1988-1994. She identifies 37 products that were approved and 10 that were rejected in this period. We track the firms to see whether they issue equity within a year of the FDA decision. The sample is quite small, with only seven equity issues following approvals (7/37 or 19%). The mean abnormal return for the seven post-approval equity issues is +0.14%, rather than the standard –3% loss we normally associate with equity issues. One interpretation of this result is that informational asymmetries are reduced for these firms with validated good-news, and thus, the deadweight costs of financing (or unexpected costs of raising funds) are reduced.[27] This suggestive evidence reminds us that the costs of financing are not only a function of the amount of funds raised, but also of the degree to which informational asymmetries exist. To the extent that the FDA decision resolves informational asymmetries, the costs of post-FDA financing might not be very large, which makes it harder to justify the transaction under the theory of cash flow hedging. Moreover, a positive FDA decision also signals that the firm has valuable investment opportunities, and Jung, Kim, and Stulz (1996)

[27] An alternative explanation is that the sample suffers from survivorship bias. We only measure the abnormal returns of the firms that we observed to issue equity. There very well may have been firms which tried to issue equity but could not because the cost would have been prohibitively high. These firms and costs should also be included in our calculation, but since we do not observe them, we cannot.

find that firms with good investment prospects suffer less of a penalty from issuing equity than do firms that do not have valuable investment opportunities. Considering Cephalon's attractive investment opportunity with Myotrophin (Contention 1), the firm's post-FDA approval cost of external finance might well be low.

Proving that the firm would face high costs of external financing is additionally challenging because of the firm's ability to put shares to the holders of CCP at a contractually-agreed upon discount. Under the terms of the contractual purchase option, Cephalon could pay both the $16 million Milestone Payment and the $40 million Purchase Option Payment in stock, valued at 95% of the average market value over the previous few weeks. This 5% discount is much smaller than the unconditional 15-20% haircut associated with a full equity offering. Furthermore, were it to choose the tender offer, Cephalon could have offered the CCP partners shares in the firm rather than cash, perhaps at roughly the same 5% discount. Using the analysts' projections that the firm's stock might be $35 conditional on FDA approval, the firm would need to issue approximately 2% and 5% of the outstanding shares to meet the Milestone and Purchase Option Payments, which reflect, respectively, one to two days trading volume.[28] Were it to pay $125 million in stock to tender for the CCP interests at a 5% discount, this would be about 3.6 million shares, or about 15% of the outstanding shares.

Using equity to tender or execute the Purchase Option would not have allowed Cephalon to eliminate informational costs of external finance. An equity payment is like a new share issue, so one might expect an equity-based purchase to lead to a share price drop, as often occurs in seasoned equity offerings.[29] However, as argued earlier, in Cephalon's case, the issuance of shares to CCP holders would occur after good information had been revealed, and the motivation for the

[28] Average daily trading volume in Cephalon from January 1, 1996 to May 7, 1997 was 762,200 shares, calculated from data from Reuters. As NASD double-counts transactions, were the shares delivered to the CCP immediately resold by them, this would equal roughly about 2 to 4 days of average *sales*.
[29] See, for example, Asquith and Mullins (1986).

transaction would have been transparent, so the penalty for equity issuance might not be severe.

Management considered, but rejected, the idea of using shares in conjunction with either the tender offer or the contractual purchase option. In explaining this decision, firm executives noted their concerns that if CCP holders received shares, they might immediately sell them, creating negative price pressure on Cephalon stock.[30] The CCP units originally had been sold by PaineWebber, but the brokerage firm's analysts did not cover Cephalon or make a market in Cephalon shares. Management feared that brokers would not strongly encourage their clients who purchased the CCP units to retain the Cephalon shares, and thus there would be massive sales of the stock.

However, existing empirical evidence calls into question whether these volumes of shares, even if immediately sold, would have a material and permanent effect on Cephalon's stock price. Existing work has focused on block trades and secondary offerings, and generally found evidence of both temporary and persistent price pressure.[31] However, in this instance, one can imagine that not all of the CCP partners would choose to sell, the sales might be spread out over time, and the sales would not be perceived as providing new information about the firm. Cephalon might also be able to modify the terms of the offer to offset the impact. It could deliver the shares over a longer time window rather than all at once, hold information sessions for the limited partners to encourage them to hold their shares, or pre-arrange for a secondary offering by the selling partners.

Even if all of the former CCP partners sold their newly acquired Cephalon shares at once, it is questionable whether the price of the stock would be affected permanently. Market microstructure research on the relationship between volume and stock price suggests that volume is

[30] A secondary consideration for opposing a tender offer with shares is the extra regulatory delay, uncertainty and expense that this step would require. If Cephalon tendered for the shares with stock, it would have needed to file an S-4, which would slow down the transaction (and possibly preclude Cephalon from enjoying the attractive accounting treatment of buying back the pre-FDA-decision R&D). As a result, if Cephalon sought to tender for the shares, managers felt that it would be easier and simpler to do so with cash.

[31] In early work Scholes (1972) finds that secondary distributions by individuals (excluding corporate officers) have a small impact on share prices (0.7%) over the ten days subsequent to the secondary offering.

not always associated with a fall in the share price, and when it is, the price often rebounds. He and Wang (1995) argue that high volume generated by exogenous information is associated with large price changes, but high volume generated by *existing* information is not. Again, it is not clear that any new information would be revealed by CCP investors flipping Cephalon stock, so there might not necessarily be a drop in the price of Cephalon stock. In Campbell, Grossman, and Wang's (1993) model sales by "liquidity" or "noninformed" traders – in this case, the CCP investors – do generate pressure that leads to price drops. However, the model predicts that there will be price *increases* on subsequent days, because rational investors willing to accommodate the selling pressure demand a reward in terms of a lower stock price (the initial drop) and a higher expected return (the subsequent increase). This prediction is confirmed empirically by Conrad, Hameed, and Niden (1994), who find that high transaction securities experience price reversals. Applied to Cephalon, this research suggests that while the price might fall initially if the CCP investors unloaded their positions *en masse*, the fall would likely not be sustained.

An alternate explanation for the managers' reluctance to use equity in a tender or for the Purchase Option is that issuing new equity would have reduced the managers' control over the firm by diluting their ownership. Considering the relatively meager ownership stake held by top management, however, this seems unlikely. As of March 1997, the eleven executive officers and directors held 363,935 shares and exerciseable options on another 762,501 shares. On a base of 24.6 million shares outstanding, these combined holdings amount to about 4.6 percent of the total shares. As noted earlier, under the assumption that Cephalon stock would reach $35 upon FDA approval, an equity-based Purchase Option deal would have diluted the outstanding stock by five percent. An equity tender offer would have diluted the outstanding equity by approximately 15 percent. Consequently, these dilutions would have reduced management ownership from 4.6 percent to 4.3 percent or 3.9 percent, depending on the purchase method. These are fairly small absolute changes in control.

Finally, while we have argued that post-FDA approval external financing costs might not be inordinately high, we can also ask whether Cephalon's investment decision would be distorted if the external financing costs *were* high. We suspect not. The return from repurchasing the rights to Myotrophin is perhaps as high as 81% or 266%, from **Table 1**. Even if Cephalon had to raise the entire amount of the tender offer in new equity and suffer a 20% deadweight loss, the value in repurchasing Myotrophin is so high that the firm would not change its investment decision. When a firm's investment decisions are not distorted by the presence of costly external finance, risk management does not create value.

In total, we have reservations about whether the costs of external financing are sufficiently high to motivate Cephalon to adopt the type of risk management used here.

An aside: How should academics and managers measure deadweight costs of financing? Event study reactions are only crude metrics of the cost of external financing. Abnormal returns reflect the capitalization of the *unexpected* impact of the offering, so expected costs of financing are not included. Also, while equity issues may depress stock prices due to the information revealed, this effect is irrelevant if the information would have been revealed anyway. Finally, event studies can only measure the costs of financings that firms executed; presumably the costs of the deals never done were higher.

As part of our study, we asked practitioners how they conceived of the costs of external financing. Managers, equity analysts and bankers framed their analysis of the costs of external funding with respect to: (a) sheer unavailability of funds; (b) total costs of obtaining funds; and (c) costs of funds with respect to dilution. In essence, they focused on the access and total cost of financing as a critical risk factor. Firms like Cephalon raise money in capital markets whose

interest in buying shares can wax and wane without warning.[32] Lerner and Merges' (1998) work documents this pattern. They track the amount of external funds raised by firms in the biotech industry from 1978 through 1985. In the 18 years that they observe, there were *no* issues of seasoned equity offerings, private placements, or any debt raised in five, eight, and eleven of the years, respectively. Managers note that during these periods financing is either simply unavailable or so expensive that they prefer not to raise funds. For managers, the cost or risk of raising external financing is like a Poisson process: in each period there is a material probability that external funds will simply become unavailable. This view is consistent with formal models of credit rationing, such as Stiglitz and Weiss (1981).

On a related point, while academics focus on *firm-specific deadweight costs* of financing, managers, analysts and bankers are equally concerned with *total costs* of funds. They consider the expected price-earnings multiples or market-to-book multiples at which they would be able to sell equity or the interest rate at which they could raise debt, rather than the wedge between the prices offered at the time and the "fair" price of their particular security. Academic evidence on "hot markets" suggests that there are times when funding becomes more or less expensive for all firms.[33] Most academic analysis would ignore these fluctuations, considering that all of these market prices are fair and thus only deviations from the fair prices (deadweight costs) are relevant. However, to the extent that these macro-cycles represent deviations from long-run "fair" prices, as managers assert, risk management programs should consider them.

Finally, managers and bankers advised us that costs of external equity financing must be measured with respect to equity dilution; that is, the fraction of the firm's equity that Cephalon

[32] This risk is noted in the Cephalon's filings: "There can be no assurance that (external) funding will be available at all or on terms acceptable to the Company. If adequate funds are not available, the Company may be required to significantly curtail one or more of its research or development programs or obtain funds through arrangements with existing or future collaborative partners or others that may require the Company to relinquish rights to certain of its technologies, product candidates or products." Cephalon Form 8-K (May 5, 1997), page 8.

[33] For a recent discussion of this phenomenon, see Bayless and Chaplinsky (1996).

would need to give away under different circumstances, and that the goal should be to raise funds with minimal dilution of existing shareholders. This analysis would require managers to combine both deadweight and absolute financing costs to calculate this dilution effect.

Our discussions with managers suggest that while the costs of external financing are central to risk management theory, neither academics nor managers have made great progress in measuring them. Furthermore, managers seem to be attuned to a richer set of costs that have not been fully considered in theoretical work.

Contention 4: The proposed call options deliver cash when Cephalon needs it most. Under a cash-flow hedging scheme, risk management is valuable because it can deliver cash when it is most useful to the firm. In this instance, the options should deliver cash when the firm needs it to buy out CCP, assuming cash payments. The buyout would occur if the FDA panel were to approve the drug, and the contention is that the firm's stock would rise—and the options would pay off—in precisely this situation.

Managers are typically barred from making predictions of the future prices of their firm's common stock, so there are no explicit estimates by Cephalon of its possible stock price, were the panel to approve Myotrophin. However, Wall Street analysts writing in the spring of 1997 estimated the impact of FDA approval of Myotrophin on the value of Cephalon's shares, as shown in **Table 4**. Their analysis confirms the intuition that the panel's approval of the drug would have a substantial impact on the market value of the Cephalon shares and options, with shares rising to a value of $30-40 if approved, and falling to $20 or less if not approved. If Cephalon stock were to rise to $30 after approval, the options would deliver $21.25 million to the firm, and at $40 per share

they would pay off $45 million.[34]

While the contention that the options would pay off when Cephalon most needed the cash seems reasonable, there could be instances in which the payoffs from the option would deviate from those sought by Cephalon. Were the panel to delay its meeting beyond the six-month exercise window, the options might expire worthless, and the firm's fund imbalance would not be addressed. Alternatively, if the stock market (or the technology sector) suffered a large downward "correction," the payoff could be reduced independent of the FDA's approval. A different structure could have indexed the payoff to the return on a broad equity index.

V. Valuing the Cephalon options

To complete our analysis, we need to make one final determination: that *the options are a cost-effective solution for Cephalon*. The executives at Cephalon recognized that they had alternative ways to meet their incremental funding need, but judged the option plan the most efficient way to fund these requirements. In particular, the firm's CFO has been quoted as saying, "We view the transaction as a good cost-benefit trade-off."[35]

Models like FSS posit deadweight costs of external financing, but are silent on whether there are deadweight costs associated with risk management products. We find that using equity derivatives as risk management vehicles might generate material deadweight costs. Cephalon's counterparty, SBC Warburg, faced the same kind of informational asymmetries that other purchasers of the firm's stock would encounter, and as a result the cost of this transaction could easily rival those of more traditional financing alternatives. Accordingly, we examine whether the

[34] Previous academic research and analyst predictions support the contention that the FDA panel's decision would have a substantial impact on the firm's stock price, and thereby on the options' value. Shane (1995) studied the impact of the FDA approval process on the market values of biotechnology firms in the period 1981 through 1994. She finds that FDA panel and full approvals lead to a mean three-day abnormal return of 1.2% and 4.5%, respectively, while disapprovals by a panel or the full FDA are associated with losses of 29.7% and 28.5%, respectively. Equity analysts' estimates seem to indicate a much stronger increase in value following FDA approval than this prior research would suggest.

[35] Quoted in Meuchner (1997).

swap of 490,000 shares for the 2,500,000 sets of capped calls was a costly exchange for Cephalon, and compare these costs to those of external financing.

Cephalon would pay no commissions or other explicit transaction costs to purchase the options, so the direct "cost" of the exchange is represented by the difference between the value of the shares delivered and the options received. The indirect cost of the transaction would be its impact on the market value of the firm, which is hard to estimate given that no other firm had ever attempted a transaction of this sort. Our analysis below will focus on the direct deadweight costs of the option purchase.

On the day the exchange was effected, the market value of the shares was $20, so for 490,000 shares, Cephalon delivered securities worth $9.8 million dollars. In turn, it received 2,500,000 sets of capped calls. A first-pass analysis might use the standard Black-Scholes (1973) model to value these call spreads. Given their maturity of six months, current interest rates of 5.5%, and the volatility of 75% (which management was using at the time),[36] each pair of call spreads would be worth $3.05 each, for an aggregate value of $7.625 million. Thus, at first glance, it would appear that the trade cost Cephalon $2.175 million, the difference between the value of the shares it delivered and the options it received.

However, this analysis fails to capture many important details of the transaction. First, the options' payoff at maturity is determined by the spread between the exercise price and the stock's average price over the 20 days prior to exercise, with three readings taken a day, so the options have an Asian feature that the Black-Scholes model is not built to handle. This averaging feature would tend to reduce the value of the options. Second, these options are being bought by a firm on its own

[36] The implied volatilites for traded seven-month options were 69% to 76%, but for one month options were 123% to 145%, suggesting that a great deal of uncertainty would be resolved by the FDA announcement.

stock, so in effect they are negative warrants due to the negative dilution effect.[37] This anti-dilution would tend to increase the value of the position acquired by Cephalon. Third, and most importantly, Cephalon faces a large stock price jump when the FDA advisory panel recommendation is issued, one day after the option contract is signed. This large jump effectively increases the volatility of the underlying stock and increases the option value. It also means that the true distribution of returns is bimodal. Fourth, from January 1996 to May of 1997, the skewness of Cephalon's daily log stock returns is -1.13 (0.26), while the kurtosis is 15.54 (.13). These values are significantly different from those expected for a normal distribution.[38] Ignoring the fact that the implied volatility surface (a graph that combines the volatility smile and term structure of volatilities) for Cephalon's options is not flat would lead to biased and inconsistent parameter estimates for the underlying valuation model, throwing into some question the robustness of the conclusions we draw as to whether the options are a cost-effective financing vehicle for Cephalon. Therefore, a model accounting for non-normality in log returns is in order.

While the first three non-standard features can be captured within a Black-Scholes framework with some adjustments, the non-normality of log returns cannot. To account for this feature, we model the stock price process using a variant of the GJR-GARCH process developed in Glosten, Jagannathan, & Runkle (1993). The risk-neutral version of this process (derived in an Appendix that is available from the authors) is given by

[37] The dilution effect occurs whether Cephalon elects to receive payment in stock or cash. This is because its underlying shares appreciate in value as the options become more in the money (because the shareholders effectively "own" the options), before any payment is received. This increase in the value of the options in turn translates to an increase in share, which again raises the value of the underlying shares, and so on. In addition, as the options become more in the money, the capital structure of the firm changes as well, since the equity is becoming more valuable. This change in capital structure also affects the valuation of the option because it changes the stock's volatility. Finally, these effects occur regardless of whether the terminal payoff of the option is in cash or stock. We will use a first-order approximation to model these effects by simply using a standard dilution adjustment to the option price. A more sophisticated model would consider the limit of these feedback processes. We thank an anonymous referee for pointing out these subtleties, and are grateful to Bob Merton for a helpful discussion on these points.

[38] A more formal goodness-of-fit test for normality can be conducted using the Kolmogorov-Smirnov D-statistic. This statistic yields a value of .49 for the log stock returns, while the 1% critical value for the test is .087. Thus, the test strongly rejects the null hypothesis of normality in the log returns.

$$\log S_{t+1}/S_t = r + \tfrac{1}{2}\sigma_t^2 + \sigma_t\varepsilon_{t+1} + \log(1+J^*1_{\{t=t^*\}})$$

$$\sigma_t^2 = \beta_0 + \beta_1\sigma^2_{t-1} + \beta_2\sigma^2_{t-1}\max(0,\phi_t-\varepsilon_t)^2 + \beta_3\sigma^2_{t-1}(\varepsilon_t-\phi_t)^2 + j^*1_{\{t>t^*\}}$$

where S_t represents the stock price, r denotes the interest rate (assumed constant), σ_t denotes the stock price volatility, and ε_t represents a standard Normal random variable. β_0, β_1, β_2, and β_3 are constant coefficients. The function ϕ_t represents the market price of risk and is given by the expression

$$\phi_t = [\alpha_0 + (\alpha_1 + \tfrac{1}{2})\sigma_t^2 - r]/\sigma_t$$

where α_0 and α_1 are constants that appear in the expected return of the objective stock price process.[39]

By allowing the stock price volatility to fluctuate, we make a first-cut effort at capturing the non-flat volatility surface implied by Cephalon's currently traded options. The time variation of volatility in the GARCH model automatically generates a volatility smile. The mean reversion of volatility and the asymmetric impact that price shocks have on volatility in the GJR version of the GARCH model allow for a term structure of volatilities and asymmetry in the volatility smile, respectively. As is shown later, these features are sufficient to not allow for rejection of normality in the residuals of the estimated model.

The jump term $1_{\{t=t^*\}}$ on the stock price reflects the large impact that the FDA committee's recommendation will have on the stock price. The jump term has a value of 0, except at time t=t* when the FDA announcement is made. At time t=t*, the Bernoulli random variable, J, determines the magnitude of the jump. Thus, with probability p, the FDA announcement causes an upward jump in the stock price, while with probability 1-p, it causes a downward jump.[40] In addition, the jump term $1_{\{t>t^*\}}$ on the volatility process indicates that the FDA announcement also changes the

[39] Due to the non-Markov nature of the GARCH process, the expected return of the stock enters into the risk-neutral process, and therefore into option prices, unlike with the Black-Scholes/Merton pricing formula.
[40] Note that these are risk-neutral quantities only and should not be interpreted as the actual parameters governing the jump process.

unconditional mean of the stock's volatility process. This jump term takes on a value of 0 until time t=t*, at which point it takes on a value of 1 and stays at that value thereafter. The jump magnitude, j, is also a Bernoulli random variable and is determined at time t=t* and remains at this value thereafter. Thus, j serves to alter the unconditional mean of Cephalon's stock variance to one of two values, depending on the direction of the FDA announcement.

We estimate all of the parameters of the model except the jump terms using time series stock price data for Cephalon ranging from January 1996 to May 1997. Parameter estimates are provided in **Table 5**. Several of the volatility parameters are found to be statistically significant, indicating the appropriateness of the GARCH model. In addition, the Kolmogorov-Smirnov D-statistic drops from 0.87 to 0.07 on the residuals, indicating that the residuals display a much better fit with a Normal distribution. The jump magnitudes and probabilities are estimated by calibrating the model to a cross-section of option prices the day before the FDA announcement. These estimates are also provided in **Table 5**.

Using this model, we estimate that the call-spreads Cephalon purchased had a value of about $3.48 each, or $8.7 million in aggregate. The Asian feature of the option is found to subtract about 3 cents of value from each option, while the dilution effect adds 13 cents. Consequently, ignoring any informational impact the option transaction may have generated, under our analysis the deadweight cost of the risk management program (the apparent mispricing of the transaction relative to our estimated price) using the warrants is $1.1 million. It would be especially instructive to know whether the price that Cephalon paid differed from the price an independent party might have paid for similar options on the firm, but we do not have this information.

This deadweight cost must be compared with the deadweight costs of the firm's alternatives. Based on management's 20% estimate of the costs of raising equity, to raise $45 million it would bear costs of $9 million. Assuming that the options would yield their maximum payoff, $45 million, upon FDA approval, the question facing Cephalon's managers was whether to bear a sure pre-approval deadweight cost of $1.1 million to fund its need, or a much higher $9

million that would be incurred only if the drug was approved. The probability of FDA approval of Myotrophin bears on the decision. The break-even probability may be calculated as follows: let π be the probability that Cephalon management assessed for Myotrophin's approval. Then, the expected deadweight cost of equity financing is given by $\pi \times 9M + (1-\pi) \times 0$. The break-even probability is approximately 12%. In other words, if management believed that approval of Myotrophin had a 12% probability or higher, then the option-based financing yields lower expected deadweight costs than issuing equity.[41] If the relevant deadweight costs are much smaller, say the 5% discount on the shares put to the CCP holders, then the breakeven rises to 49%.[42] If we think that there are virtually no costs of external financing in the good news state, then the option proposal is clearly inferior. None of these breakevens captures the possibility that Cephalon might be unable to raise equity later at virtually any price.

Bankers have suggested an alternative break-even approach that managers should consider, consistent with their concerns about minimizing economic ownership dilution of existing equity holders. To generate $45 million, the option plan requires that Cephalon issue 490,000 shares in advance, or 1.8% of the existing shares (assuming that the post-FDA stock price exceeds $39.50). Were it to raise equity at $35 per share (net of all costs) after learning of the FDA's approval, it would need to issue 1.29 million shares, or 4.7% of the firm's shares. In both cases, the firm raises $45 million only if the FDA approves the drug, and managers have to consider what fraction of the firm they wish to give up to do so. Here, the break-even is slightly below 40%, indicating that if the deal is more than 40% likely to proceed, then existing shareholders might prefer the option proposal

[41] This comparison ignores (a) the time value of money, which would make the future losses due to the equity sale smaller in present value, and (b) apparent risk aversion by the Cephalon decision-makers, which would make the certainty-equivalent of the risky outcome more than the expected loss given a concave utility function. The first factor would tend to raise the break-even and the second factor would tend to lower the break-even. The apparent *risk-neutral* probability of approval can be calculated conditional on the point estimates of the conditional stock prices given by the analysts reported in Exhibit 5, and tends to range from 20-45%.

[42] The purchase option requires Cephalon to pay either $40.275 million in cash or $42.369 million in shares, valued at their average market value in the period prior to delivery. One could think of this difference as the deadweight cost of this transaction.

in that they would prefer to give up a smaller fraction of the firm to obtain the same economic resources.

These breakevens may provide management with some guidance for thinking about the different alternatives. Given their priors of the likelihood of approval, managers could determine which alternative provides the lowest deadweight costs or the lowest dilution of existing shareholders.

VI. Was it really risk management? Alternative explanations

So far in this paper we have analyzed the derivative transaction under the stated management rationale—as an integral part of their overall risk management strategy. As we work through our analysis to back up this explanation, not all of the logical steps needed to support this argument can be firmly defended. In particular, it is arguable that Cephalon had insufficient cash to repurchase the rights to Myotrophin or that external financing was so expensive so as to justify the option transaction.

Some commentators felt that the deal was not risk management, but rather an attempt to "signal to the market" the firm's confidence about the upcoming FDA approval.[43] However, this signaling interpretation seems inconsistent with the facts at hand. The outcome of the FDA approval process would be revealed publicly within a month, and earlier revelation of the firm's estimates of success would not seem to have any impact on the firm's long-run ability to finance itself or on executive compensation. There were no material decisions that would be made prior to the FDA approval that earlier revelation of information would affect.

Other observers suggested Cephalon's transaction might be a high-tech share buyback. Through its exchange of 490,000 shares for 2,500,000 capped call options the firm established a state-contingent buyback program, where the *ex post* magnitude of the buyback depends on the

[43] See Hamilton (1997) and Ward (1997).

payoff of the options. Were the FDA to approve the drug and were the calls to mature in the money, the transaction would lead to the net buyback of 2,010,000 shares if Cephalon were to settle the transaction by purchasing shares at the strike rather taking a cash payment. Conversely, were the FDA to disapprove the drug and the calls to mature worthless, the firm would have issued 490,000 shares.[44] However, given that the firm was prepared to issue shares, and in light of its intention to cash-settle the options, it is difficult to conceive of the transaction as a buyback program.

Finally, others saw the transaction as a way to make an informed and leveraged bet on a product that Cephalon knew well, or a "let's-raise-the-ante" strategy.[45] Based on our conversations with the managers, this motivation seems unlikely or secondary, although we acknowledge that even in a clinical study with a willing company, it is impossible to reject this alternative explanation out of hand. Financial theory does not rule out speculative trading, and it can justify precisely these kinds of bets, where firms have substantial information and are capable of bearing the losses if they are wrong.[46]

Certainly, private information by management may help explain the deadweight cost of the options risk management strategy. SBC Warburg's traders might have feared that Cephalon was better informed than they were about either the "true" *level* or *volatility* of Cephalon stock price and adjusted the option price accordingly. By trading shares for options, the deal mitigates some of this problem, because the value of both shares and options would be determined jointly. However, as the deltas of the shares and option package are not equal, there could remain conflicts of interest.

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[44] *Ex ante*, the firm's net position was a buyback of 445,000 shares, evaluating the delta-equivalent share position in its purchased calls.

[45] See Pauly (1997).

[46] See Stulz (1996) for a discussion. In Cephalon's case, the firm's officers might personally benefit from increasing the firm's bet on its new product. The executive officers and directors jointly held many more options on the firm than shares in the firm: the eleven officers and directors held 363,935 shares as of March 1997, but exerciseable options on 762,501 shares. As option holders, they might prefer transactions that increase the volatility of the firm's equity. In this case, the proposed option transaction effectively levers up the firm and increase the stock's volatility . This type of preference would be consistent with the evidence from Tufano (1996) or Schrand and Unal (1998), who find that firms whose managers hold more options appear to tolerate higher firm volatility.

To understand Cephalon's latitude for profiting from private information under the proposed deal, we use the model in the previous section to re-estimate the value of the proposed stock-for-options trade for a range of stock prices and long-run volatilities (unconditional means of volatilities). Suppose that Cephalon's managers knew the "true" stock price or volatility or both, while SBC had access only to less-informed public information. Under what circumstances could its exchange of stock-for-options be a valuable speculative position for Cephalon? In **Figure 2**, we plot the profitability to Cephalon of the proposed trade under various stock prices and volatilities.

If the managers had private information about only the true volatility, the proposed structure would not permit them to profitability enter into the exchange with SBC. There is no volatility that would make the trade a positive one to Cephalon if the $20 market price of the stock were an unbiased estimate of the firm's value on the day the deal was executed. Thus, Cephalon could not have traded profitably strictly on the basis of private information regarding the true level of long-run volatility.

However, if Cephalon had private information that its "true" stock price exceeded $22 (10% above the market price), it could have profited from the transaction (given the current volatility). However, in this case it would have done better by buying the options *in cash*, rather than paying for them in *undervalued stock*.

Nevertheless, this exercise illustrates that if a firm were to have private information on the value of the underlying asset (the stock), it could profitably trade derivatives on the stock, or in this case, trade stock for calls. The informational asymmetries regarding the underlying plague the equity derivative as well, which may explain the apparent transaction costs of using equity derivatives as a risk management tool.

VII. Followup and Implications

Cephalon issued a press release on Wednesday, April 9, 1997, announcing its proposal to enter into the option transaction. *Bloomberg* reporters filed two stories on the transaction that day, as did *Reuters*, and stories appeared in the print media on Thursday, April 10. The transaction was the subject of a column in *Barrons* magazine, dated Monday, April 14. **Figure 3** reports the market reaction to Cephalon's announcement. Over the three-day window around the initial announcement on April 9, 1997, Cephalon enjoyed positive abnormal returns of +3.3% or +2.3%, using as market indices the CRSP value-weighted NYSE/AMEX/NASDAQ and Russell 2000 indices, respectively. This suggests that the informational impact of the transaction was positive: unlike an equity issuance, there was an upward revision in firm value.

On May 8, the day after the option deal was executed, the FDA advisory panel convened. Trading in Cephalon stock was halted that day. The panel voted 6-3 that there was not "substantial" evidence that Myotrophin was effective in the treatment of ALS, and this information was revealed after trading hours.

On Friday, May 9, trading in Cephalon resumed, and the stock closed at $13, a drop of 35% from the last closing price. This corresponds to a one-day abnormal loss of approximately 36%, calculated as shown in **Figure 3**. Volume for the day was 8.4 million shares, 10.5 times larger than the average daily trading volume in the period between Cephalon's announcement of the option transaction and the FDA advisory panel meeting. Subsequently, the FDA delayed its recommendation on Myotrophin beyond the six-month option window. The average closing price for the twenty trading days preceding the option maturity was about $12.50, and as a result, the options expired worthless.

While the FDA panel's decision made Cephalon's "backwards" insurance policy unnecessary, one cannot conclude that the purchase of options was an imprudent corporate transaction based on this *ex post* assessment. Rather, one must probe the *ex ante* rationales for the transaction, using data that managers had at that time. Our analysis suggests that many—but not

all—of the premises that would justify the option transaction can be supported. Had the FDA approved Myotrophin, Cephalon would have had a valuable investment opportunity, the right to buy back the rights to the drug. Standard external financing would have been expensive for Cephalon, as it is for other firms, although probably much less so in the wake of a positive decision by the panel. Finally, the option transaction was likely to deliver cash to Cephalon when this investment opportunity was presented.

However a few key premises behind the cash-flow hedging arguments were missing or questionable. It is not clear that the firm needed *any* external financing to enjoy the positive returns from buying back the rights to Myotrophin. Its need to raise extra external funds arose from the desire to enjoy a particular type of accounting treatment and its aversion to paying in stock. If the firm were willing to forgo the accounting that would produce higher subsequent earnings and pay for the contractual purchase option with equity, or if it were willing to pay for some or all of the tender offer with equity, it could have funded the cash requirements of the buyback with internal resources. The decision seems predicated on two assumptions that we find hard to judge, regarding the impact of differing accounting treatments and the distributions of stock to the limited partners on market value. While we respect that managers must make decisions given imperfect information, we have reservations whether this transaction can be justified given these factors. Finally, we suspect that raising external financing after the FDA approved the drug might have been a relatively low-cost choice.

More broadly, we believe the Cephalon case raises a number of interesting questions for students and practitioners of risk management. First, while accounting treatment sometimes discourages firms from engaging in risk management, here it served to encourage Cephalon to engage in a particular risk management strategy. In particular, the treatment of R&D expenses gave rise to a preference for tendering for the limited partnership interests, which in turn created a cash flow need beyond the resources available to the firm. The "big bath" accounting treatment sought by the firm is understudied and we suggest can support additional research. While this particular

form of accounting-induced risk management is probably rare, the relationship between accounting rules and risk management behavior is an important area for future study.

Second, risk management is predicated upon the notion of costly external finance. Here, we tried to get managers to quantify the costs of financing. While part of their answer was consistent with academic theory, their concerns for the absolute cost and availability of financing are not fully considered by risk management theory. Financing risk is a critical uncertainty that motivated this transaction. Managers inhabit a world that can suddenly become inhospitable to financing their firms, and overall market levels and prices motivate risk management more so than the firm-specific "deadweight" costs of financing. Further research into the various costs of external financing is required if we are to implement risk management programs.

Third, academic models of risk management often assume that external financing has deadweight costs, while risk management does not. Yet, the use of equity derivatives as a risk management tool may subject the firm to the same sort of information asymmetries and deadweight costs that an equity issue would. Our contribution here is to attempt to quantity the size of these deadweight costs and explicitly compare them to those that would arise from more traditional financing. We also attempt to measure the magnitude of informational asymmetries that might allow a firm to profitably trade on its own stock, and which likely affect the level of transaction costs.

Fourth, risk management decisions cannot be made in a vacuum. These choices must be evaluated in the context of the full menu of financing and investment decisions in the firm. Here, the firm had a valuable existing contractual option (for which it had already paid), whose existence might obviate the need to purchase options. More generally, it could have delivered shares to the partners under the tender offer, then carefully managed the resultant sell-off, perhaps through a secondary offering, to minimize the stock price impact of the distribution.

Finally, we see that corporate managers who are using relatively simple pricing models, may be at a competitive disadvantage when analyzing even seemingly "simple" equity derivatives.

Our analysis of the value of the negative call warrants purchased by Cephalon differs materially from the first-pass analysis, and if corporations hope to transact in equity derivatives, they may need additional in-house financial engineering skills to ensure that they are getting fair execution for these trades.

In conclusion, we can learn a great deal from Cephalon's experience. The use of equity derivatives as a risk management vehicle is likely to increase in importance over time, and we can leverage firms' experiences to make these customized transactions better meet the needs of corporations and their shareholders.

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Table 1
Analysis of the value of repurchasing the rights to Myotrophin from Cephalon Clinical Partners, conditional on approval by FDA

Comparison of Alternative Means to Repurchase Myotrophin Rights

US$, millions

Myotrophin revenue projections	NOTE	Parameter	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
ALS															
United States ALS Population			25000	25000	25000	25000	25000	25000	25000	25000	25000	25000	25000	25000	25000
Penetration rate			0%	30%	50%	60%	70%	70%	70%	70%	70%	70%	70%	70%	70%
Revenue/patient (US$, million)		0.01	$ 0.015	$ 0.015	$ 0.015	$ 0.015	$ 0.016	$ 0.016	$ 0.016	$ 0.016	$ 0.016	$ 0.016	$ 0.017	$ 0.017	$ 0.017
US Revenue			$ -	$ 113.6	$ 191.3	$ 231.8	$ 273.2	$ 275.9	$ 278.6	$ 281.4	$ 284.2	$ 287.1	$ 290.0	$ 292.9	$ 295.8
European ALS Population			35000	35000	35000	35000	35000	35000	35000	35000	35000	35000	35000	35000	35000
Penetration rate			0%	10%	25%	30%	35%	40%	45%	50%	50%	50%	50%	50%	50%
Revenue/patient (US$, million)		0.01	$ 0.015	$ 0.015	$ 0.015	$ 0.015	$ 0.016	$ 0.016	$ 0.016	$ 0.016	$ 0.016	$ 0.016	$ 0.017	$ 0.017	$ 0.017
European Revenue			$0	$53	$134	$162	$191	$221	$251	$281	$284	$287	$290	$293	$296
Peripheral Neuropathies															
Potential revenues			$0	$5	$13	$26	$38	$43	$48	$55	$62	$70	$79	$89	$101
Total revenues			**$0**	**$171**	**$338**	**$420**	**$502**	**$539**	**$578**	**$618**	**$630**	**$644**	**$659**	**$675**	**$692**
Payments under tender offer			**125**												
Contractual purchase option															
Milestone Payment			$16												
Purchase Option pmt					$40										
Royalty payment calculation:															
Royalty rate			10%	10%	10%	10%	10%	10%	10%	10%	10%	5%	5%	5%	5%
Royalties to CCP			$0	$17	$34	$42	$50	$54	$58	$62	$63	$32	$33	$34	$35
Cumulative royalties			$0	$17	$51	$93	$143	$197	$255	$317	$380	$412	$445	$479	$513
Payments under purchase option			**$16**	**$17**	**$74**	**$42**	**$50**	**$54**	**$58**	**$62**	**$63**	**$32**	**$33**	**$34**	**$35**
Differential cash flow			**-$109**	**$17**	**$74**	**$42**	**$50**	**$54**	**$58**	**$62**	**$63**	**$32**	**$33**	**$34**	**$35**
Internal rate of return			**41%**												

Cash flow from alternative buy back means	NOTE	Parameter	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Revenues from Myotrophin			$0	$171	$338	$420	$502	$539	$578	$618	$630	$644	$659	$675	$692
COGS		35%	$0	$60	$118	$147	$176	$189	$202	$216	$221	$225	$231	$236	$242
Pretax contribution to profits			$0	$111	$220	$273	$327	$351	$376	$401	$410	$419	$428	$439	$450
Taxes		34%	$0	$38	$75	$93	$111	$119	$128	$136	$139	$142	$146	$149	$153
Aftertax contribution to profits			$0	$73	$145	$180	$215	$231	$248	$265	$270	$276	$283	$290	$297
Cephalon's share of profits	(1)	50%	$0	$37	$73	$90	$108	$116	$124	$132	$135	$138	$141	$145	$149
Marginal AT cash flow from tender	(2)		**($83)**	**$37**	**$73**	**$90**	**$108**	**$116**	**$124**	**$132**	**$135**	**$138**	**$141**	**$145**	**$149**
IRR			**81%**												
NPV at analyst-discount-rate	(3)	25%	**$269**												
Marginal AT cash flow from purchase option	(4)		**($11)**	**$25**	**$24**	**$62**	**$75**	**$80**	**$86**	**$92**	**$94**	**$117**	**$120**	**$123**	**$126**
IRR			**266%**												
NPV at analyst-discount-rate		25%	**$226**												

These proforma projections draw upon analyst reports (Malloy (March 20, 1997), Wilson and Schmidt (January 26, 1996), and Lonergan, Stone, and Reed (February 20, 1997)) and other public sources, but reflect the authors' interpretations of a composite of these professional analyses. Further details are available from the authors.

Notes:

(1) Cephalon and Chiron split after-tax profits on Myotrophin equally. This is indicated in Cephalon, Inc.'s 10-K, December 1996, p. 53.

(2) Represents Cephalon's share of profits less the payment under the tender offer, which we believe is a taxable expense. This calculation does not include a terminal value, which understates the value of buying back Myotrophin.

(3) This discount rate is used by Wilson and Schmidt, (January 26, 1996, p. 11), and Lonergan et al. (February 20, 1997, p. 3.) in valuing Cephalon.

(4) Represents Cephalon's share of profits less the payment under the contractual purchase option, which we believe are taxable expenses. This calculation does not include a terminal value, which understates the value of buying back Myotrophin.

Table 2
Proforma projections of Cephalon's internal cash flow and investment needs

US$, millions			If tender for CCP Interests			If exercise purchase option		
Cash flow projections	NOTE	Parameter	1997	1998	1999	1997	1998	1999
Myotrophin pre-tax profits			$0	$56	$110	$0	$56	$110
Other pretax drug profits			$21	$49	$65	$21	$49	$65
Net interest income (expense)			$1	($5)	($6)	$3	($3)	($1)
Research and development			($68)	($75)	($81)	($68)	($75)	($81)
SG & A			($37)	($40)	($55)	($37)	($40)	($55)
Payment to CCP	(1)		($125)	$0	$0	($16)	($17)	($74)
Total pretax profits			($208)	($16)	$33	($97)	($30)	($37)
Taxes	(2)	0%	$0	$0	$0	$0	$0	$0
After-tax profits			**($208)**	**($16)**	**$33**	**($97)**	**($30)**	**($37)**
Non-cash items and Working capital needs	(3)		($7)	($7)	($7)	($7)	($7)	($7)
Cash from operations			($215)	($23)	$26	($104)	($37)	($44)
Cash from investing activities	(4)		($6)	($6)	($6)	($6)	($6)	($6)
Cash from financing activities								
Scheduled repayments	(5)		($5)	($2)	($1)	($5)	($2)	($1)
Proceeds from convertible			$30			$30		
Cash flow requirement	(6)		($196)	($30)	$19	($85)	($44)	($51)

These proforma projections draw upon analyst reports (Malloy (March 20, 1997), Wilson and Schmidt (January 26, 1996), and Lonergan, Stone, and Reed (February 20, 1997) and other public sources, but reflect the authors' interpretations of a composite of these professional analyses. Further details are available from the authors.

(1) From Table 2.
(2) Cephalon has a net operating loss of $75 million as of the beginning of 1997, and would generate additional losses in the subsequent years so that no cash taxes would be paid over the three-year horizon.
(3,4) Authors' estimate from historical data.
(5) Repayment schedule given in Cephalon, Inc., 10-K, December 1996.
(6) Represents the amount of cash that would have to be raised either by reducing the existing cash balance or by new financing. Cephalon held cash and marketable securities balance equal to $146 million as of December 31, 1996. It anticipated being able to raise $100 million in financing over the coming two years, excluding funds raised through the proposed option transaction.

Table 3

Cephalon's external financing history and the market impact of its financing announcement, 1993-1997

Abnormal returns for Cephalon stock are calculated using daily data for Cephalon stock, the CRSP value-weighted index, and the Russell 2000 index. The Russell 2000 data are from Datastream. The abnormal return on day t, ε_{ct}, is given by $\varepsilon_{ct} = R_{ct} - (\alpha + \beta R_{mt})$, where parameters α and β are estimated using the Scholes and Williams (1977) correction for nonsynchronous trading. The estimation period for the parameters is the 250-day period preceding the event window. The event window is a three-day period commencing the day before the announcement, where the date of the announcement is considered day 0 in event time. Accordingly, the event window corresponds to days -1, 0, and +1. The announcement date is identified by a search on Lexis/Nexis. In all cases but one, the 1993 equity issue, the first press report of the financing corresponds exactly to the date the intention to issue new equity is first filed with the SEC. In 1993, Cephalon filed with the SEC on February 8, and the first press report is on February 9. In this case, February 8 is considered day 0. The column labeled "Fees" reports the underwriting expenses and other expenses as a percentage of the gross proceeds. The columns "CAR" reflect the cumulative three-day abnormal returns, as described above. The columns "Offering Dilution" report the dollar value of the cumulative abnormal returns divided by the gross proceeds.

	Issue Information				Fees	Offering dilution		CAR	
Year	**Type of Financing**	**Announcement and Issue Date**	**Terms of Issue**	**Gross Proceeds**	**(% of Offering)**	**CRSP VW**	**Russell 2000**	**CRSP VW**	**Russell 2000**
1997	Convertible Private Placement	Announcement: 1/16/97 Completed: 4/8/97	7% int. in year 1; 10.75% later if not converted. Convertible into stock at 6% discount to a market price at conversion.	$30 million	na	+154.7%	+177.7%	8.1%	9.3%
1995	Public Stock Offering	Announcement: 6/27/95 Issue: 8/1/95	3.45 million shares at $22.50/share	$73.037 million	5.9% (excludes expenses)	-32.5%	-30.4%	-7.6%	-7.1%
1994	Public Stock Offering	Announcement: 1/10/94 Issue: 2/9/94	3.795 million shares at $15.00/share	$53.328 million	5.9%	-8.1%	0.0%	-2.0%	0.0%
1993	Public Stock Offering	Announcement: 2/8/93 Commenced: 4/7/93	2.3 million shares at $9.50/share	20.539 million	7.6%	-42.0%	-29.3%	-7.6%	-5.3%

Table 4
Analysts' projections of the value of Cephalon common stock, conditional on whether FDA panel were to approve Myotrophin.

Analyst	Date of report	Estimate of probability of panel approval	Value if approved	Value if not approved
Hambrect & Quist (1)	March 20, 1997 May 9, 1997	not given	$30-35 per share in twelve months, "based on our assumption of a favorable FDA review of both Myotrophin and Provigil." (March 20, 1997)	After the FDA meeting, before trading: "We anticipate that Cephalon's stock will trade off sharply this morning. Our best sense is that the stock could find support in the $12 range." (May 9, 1997)
Cowen (2)	February 20, 1997	not given	$40-45 per share at the end of fiscal year 1997 "keyed primarily to Myotrophin's success."	"Shares have a $20 present value, ex(cluding) ALS."
UBS Securities Equity Research (3)	May 7, 1997	70%	"A positive outcome should send Cephalon's stock into the thirties since out model predicts Cephalon to earn $2.21 in 2000, implying a current stock value of $37 (based on a 30 multiple and a 25% discount rate)."	"A rejection would most likely knock the stock down to the low teens."

Notes:
(1) Malloy (March 20, 1997; May 9, 1997).
(2) Lonergan, Stone, and Reed (February 20, 1997).
(3) Wilson and Schmidt (May 7, 1997).

Table 5

Parameter Estimates for Cephalon Stock Price Process

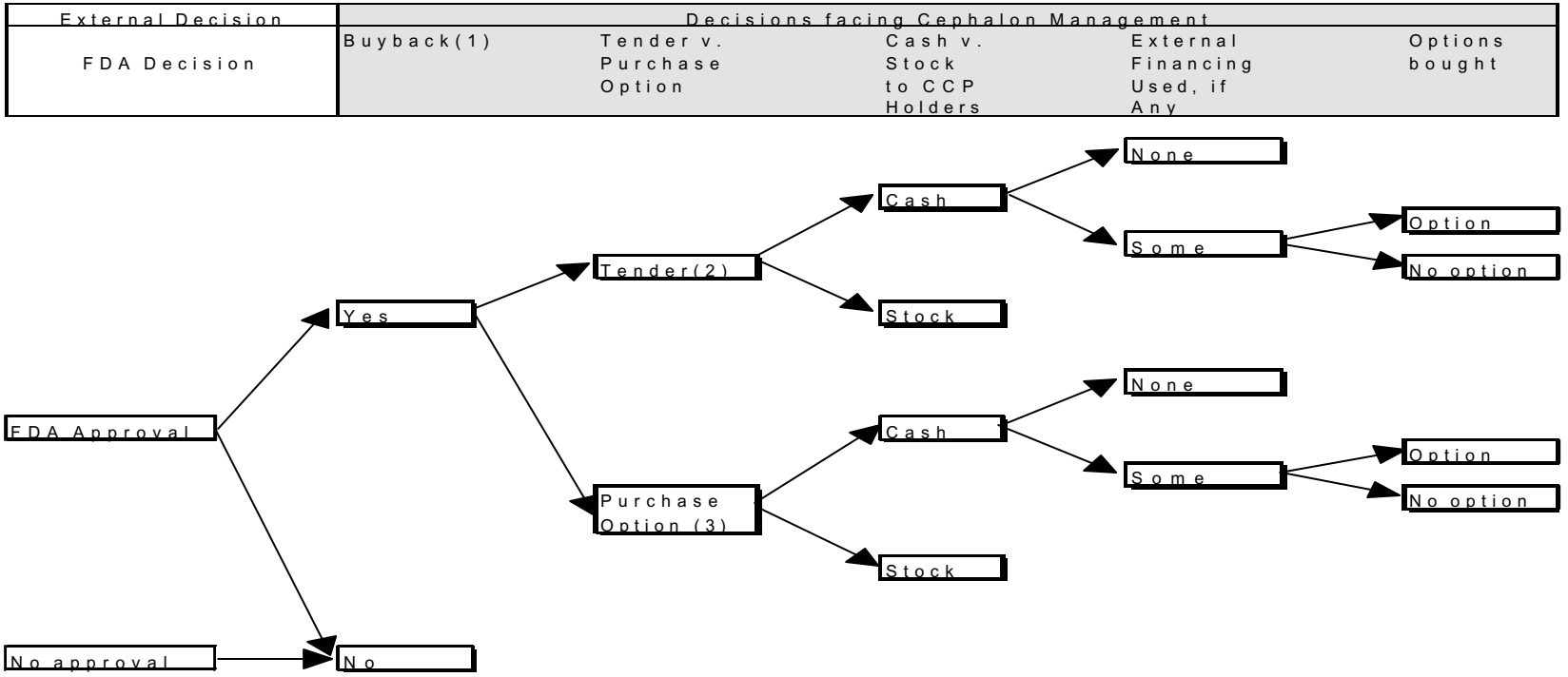
This table provides estimates for the GJR-GARCH model

$$S_{t+1}/S_t = \exp[\alpha_0 + \alpha_1\sigma_t^2 + \sigma_t\varepsilon_{t+1}]*(1 + J*1_{\{t=t^*\}})$$
$$\sigma_t^2 = \beta_0 + \beta_1\sigma_{t-1}^2 + \beta_2\sigma_{t-1}^2\max(0,\varepsilon_t^2) + \beta_3\sigma_{t-1}^2\varepsilon_t^2 + j*_{1\{t>t^*\}}$$

where t* represents the date of the FDA announcement. The estimates, except for jump parameters, were obtained using 341 observations for Cephalon beginning January, 1996 and ending May 6, 1997. The jump parameters were estimated by calibrating the stock process to a cross-section of option prices on Cephalon stock, on May 6, 1997. As such, the jump magnitudes represent risk-neutral quantities.

Parameter	Estimate
α_0	-0.0026 (0.0014)
α_1	0.1040 (0.3015)
β_0	0.0018 (0.0003)
β_1	0.1646 (0.0061)
β_2	0.0486 (0.0517)
β_3	0.1364 (0.0590)
J (up)	1.19
J (down)	0.64
j (up)	0.17
j (down)	0.25

Figure 1
Schematic of Cephalon's Financial Obligations to Cephalon Clinical Partners, L.P.



(1) Regulatory approval of Myotrophin in the U.S. or Europe would trigger the requirement to make a Milestone Payment to the CCP holders, equal to $16 million. Cephalon could choose to make this payment in cash, stock, or any combination, at their option.
(2) The 8-K notes that there is "no assurance that any agreement can be reached with the General Partner to acquire the limited partnership interests. Even if an agreement can be reached, the Company estimates that to reach an agreement the purchase price could be significant, possibly in the $125 million range," including the Milestone Payment.
(3) The Purchase Option would be exercisable for a 45 day window beginning the earlier of (a) the later of (i) the month in which the partners received interim license payments equal to 15% of their capital contributions, or (ii) 24 months after the first commercial sale of Myotrophin in the territory, or (b) 48 months after the first commercial sale within the territory. As a practical matter, (a.i) appears to be the binding constraint. Under the purchase option Cephalon would buy back the rights by making a purchase option payment, equal to $40.275 million in cash or $42.369 million in stock, plus paying royalties. Royalties would be 10.1% of sales (reducing to 5.0% after a specified return is earned by the former limited partners) of Myotrophin sales in North America and Europe for an 11-year period.

Figure 2

Contour Plot of Profit/Cost to Cephalon for Various "True" Stock Prices and Long-Run Volatilities

This plot shows the total dollar gain or loss (in millions) to Cephalon from exchanging shares for options if the true stock price and the true unconditional mean of volatility were different from that given by the stock price and estimated volatility on the day of the transaction. Each line in the graph below represents a profit contour. The label for the contour represents the profit level of that contour. For example, the $2 M contour shows all of the true stock price–volatility combinations that would result in a $2 million profit to Cephalon for the transaction. The stock price and implied volatility on the day of the transaction are shown by the heavy black square on the graph.

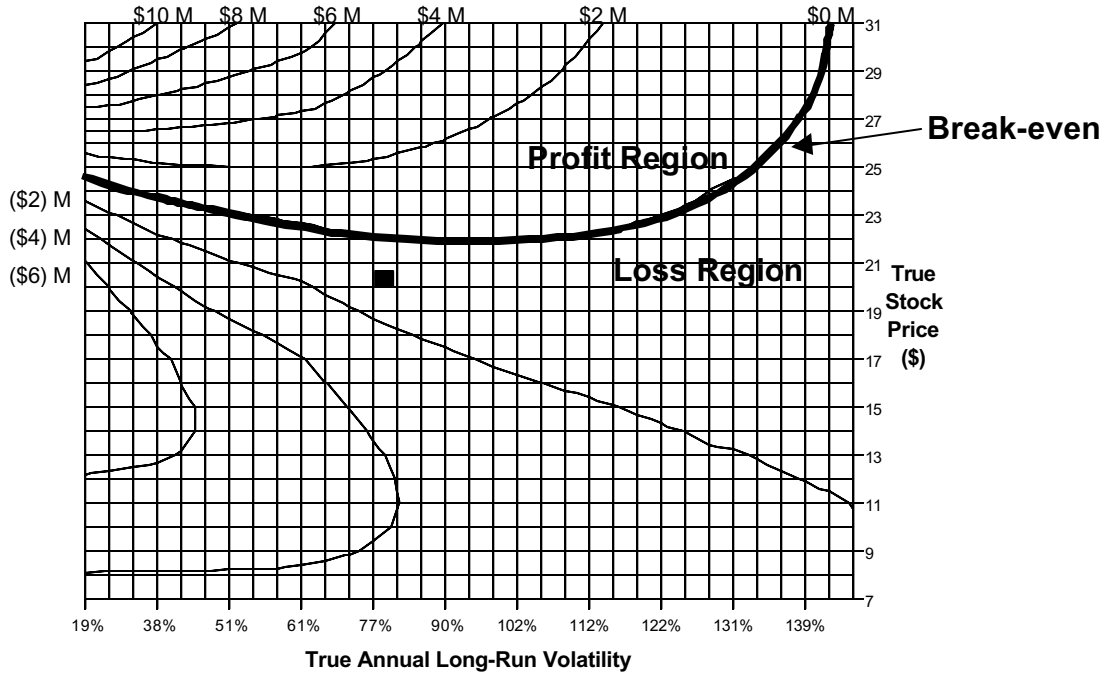
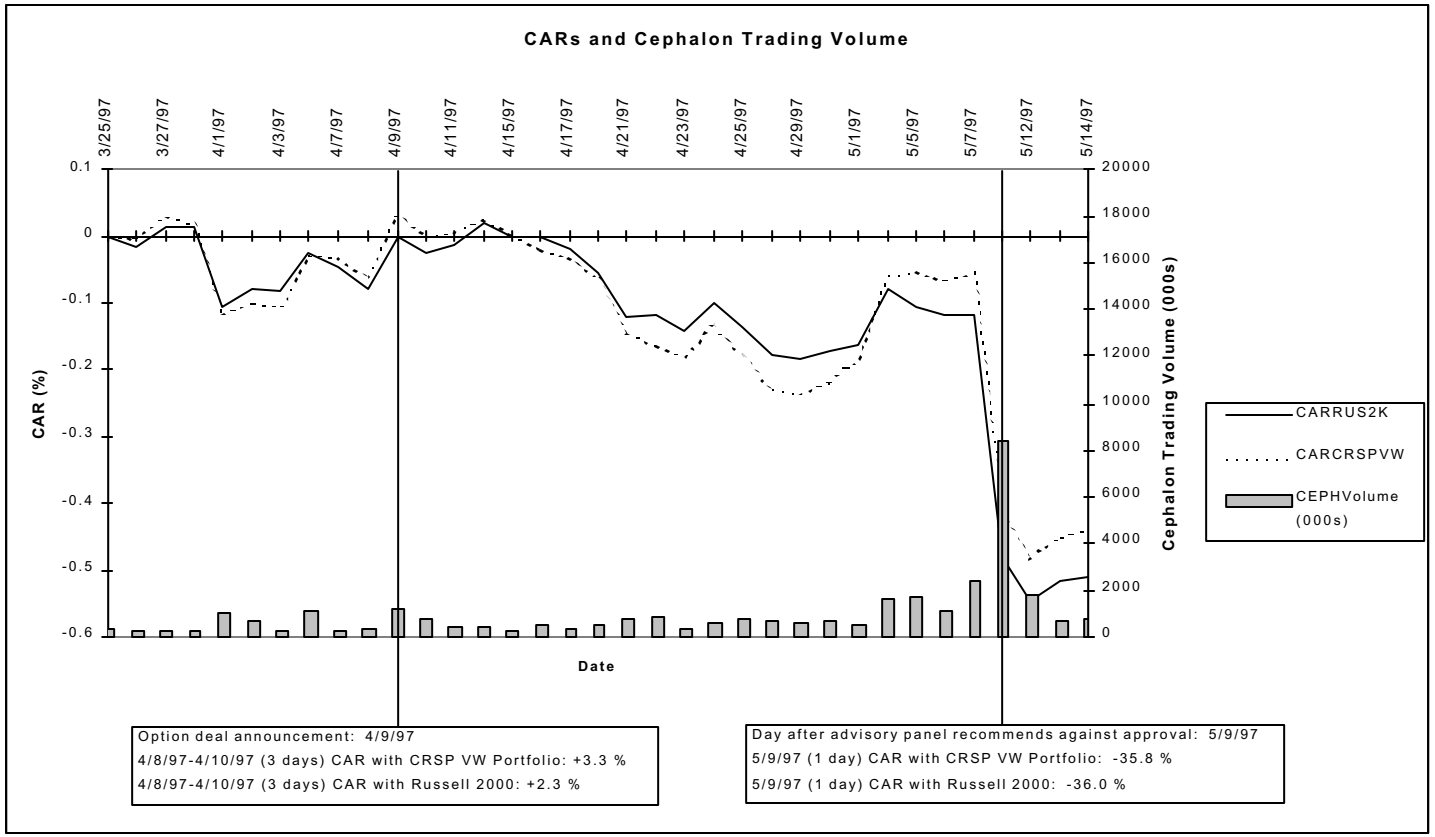


Figure 3
Market Reaction to Announcement of Cephalon Option Transaction and FDA Decision



Abnormal returns are calculated using daily data for Cephalon stock, the CRSP value-weighted index, and the Russell 2000 index. The Russell 2000 data are from Datastream. The abnormal return on day t, ε_{ct}, is given by $\varepsilon_{ct} = R_{ct} - (\alpha + \beta R_{mt})$, where parameters α and β are estimated using the Scholes and Williams (1977) correction for nonsynchronous trading. The estimation period for the parameters is the 250-day period preceding the event. The event window for the initial announcement is a three-day period centered around April 9, 1997, the date of the announcement. The abnormal return for the second announcement is calculated only for the first trading day following the FDA announcement. There was no trading of Cephalon stock on May 8, 1997, the date of the panel meeting.

A Appendix

Many professionals may value equity options such as those purchased by Cephalon with the Black-Scholes/Merton model. Valuation using this model was presented in the text. However, a number of contractual features of the Cephalon options, as well as the particular situation of the firm, result in the Black-Scholes/Merton model being inappropriate in this situation. In order to value these options more accurately, we develop and estimate a GARCH-Jump option pricing model for the underlying stochastic process which includes features such as accretion effects and path-dependency of the contractual provisions. With more and more firms transacting in derivatives on their own stock, the modelling used in this paper should see wide applicability.

This model relaxes several of the assumptions in the Black-Scholes/Merton model, which allows for better modelling of several contractual features of the options. First, the claims give Cephalon the unusual ability to buy an option on its own stock. Thus, these claims are in fact warrants.[1] However, since the warrants are owned by Cephalon, the dilution effect typically caused by exercising warrants works in the reverse direction here, and therefore must be modeled implicitly.

Second, a lognormal distribution is a poor descriptor of the conditional distribution of Cephalon's stock price. This is easily seen from recent historical data on Cephalon's stock. The stock price displays both skewness and excess kurtosis. To accommodate these patterns, we use a stochastic volatility process for the stock price. This immediately brings up the issue of estimation, which is not trivial for stochastic volatility models. To simplify the estimation problem we calculate the discrete-time GARCH process that converges to the stochastic volatility model, similar to Nelson (1990), and then estimate this GARCH process.

In addition to stochastic volatility, we need to incorporate the fact that a jump event will affect the stock price during the life of the options. This event (the FDA announcement) will have a substantial impact on the stock price. A jump process such as that used in Merton (1976) cannot be used here because the jump will occur on a known date, though with an unknown direction and

[1] Several papers have dealt with the topic of warrant pricing. Examples include Schwartz (1977) and Constantinides (1984). For this paper, we utilize the simple approach of Galai & Schneller (1978). Crouhy & Galai (1994) and Schulz & Trautmann (1994) examine a more accurate valuation technique that accounts for the leverage of a firm.

magnitude. To account for these features, the stock process is modeled using a GARCH-Jump process where the jump is a one-point jump. This model may be used to price options on any security where the underlying stock will be hit by a jump at a known date, though of unknown magnitude and direction. Examples include options on firms that are scheduled to make a public announcement, firms in the midst of major litigation where it is known that a judgement will be made within a narrow time frame, or firms in the middle of merger negotiations, where again, the results will be announced within a narrow time frame.

Third, the options are path-dependent, in that the value of the options at expiration depends on the average of the stock price over the month preceding the expiration date. All of these features could contribute substantially to the price of the Cephalon warrants, and each needs to be incorporated into any valuation model.

A.1 Time-Varying Volatility

The pricing of these warrants depends critically on the conditional distribution of Cephalon's stock price. As mentioned above, under the commonly-used assumption in Black-Scholes/Merton that the stock price follows a geometric Brownian motion process

$$\frac{dS}{S} = \mu\, dt + \sigma\, dW_t \tag{1}$$

where μ and σ are constants, W_t is a Wiener process, and the stock's conditional distribution is lognormal. However, if (1) is estimated for Cephalon's stock, an inspection of the residuals from the estimation shows that the assumption of normality is strongly violated. From January 1996 to May of 1997, the skewness of Cephalon's daily log stock returns is -1.13 with a standard error of .26, while the kurtosis is 15.54 with a standard error of .13. These values are significantly different from those expected for a normal distribution. A more formal goodness-of-fit test for normality can be conducted using the Kolmogorov-Smirnov D-statistic. This statistic yields a value of .49 for the log stock returns, while the 1% critical value for the test is .087. Thus, the test strongly rejects the null hypothesis of normality in the log returns.

To account for this non-lognormality in Cephalon's stock returns, we

incorporate stochastic volatility using the process

$$\begin{aligned} \frac{dS}{S} &= (a_0 + a_1\sigma_t^2)\,dt + \sigma_t\,dW_s \\ d\sigma_t^2 &= b_0(b_1 - \sigma_t^2)\,dt + b_2\sigma_t^2\,dW_\sigma \end{aligned} \tag{2}$$

where a_0, a_1, b_0, b_1, and b_2 represent constants, and W_σ is a Wiener process that has a constant correlation ρ with W_s. Due to the stochastic nature of the volatility process, this model exhibits excess kurtosis. In addition, depending on the sign of the correlation between the Wiener processes, the model can also display positive or negative skewness. The other assumptions implicit in the model above, such as mean-reverting volatility and volatility impacting the stock return's drift, are based on empirically observed characteristics common to a wide cross-section of stocks. Thus, the model in (2) is capable of displaying the key patterns of non-lognormality observed in Cephalon's stock price.

However, stochastic volatility processes of this form are extremely difficult to estimate. Common techniques used have included GMM (and EMM), Kalman filtering, simulated maximum likelihood, and Bayesian estimation.[2] The choice between these usually becomes a tradeoff between accuracy and computation time.

We approach this estimation problem in a slightly different manner. Instead of modifying the estimation technique, we will instead modify the stochastic process so that it is easy to estimate and then rely on convergence theory to obtain reliable estimates and prices. To this end, we modify the basic geometric process above to incorporate a time-varying volatility that is conditionally deterministic. The model that is used to accomplish this is the GJR GARCH(1,1)-in-mean model first introduced in Glosten, Jagannathan, & Runkle (1993):

$$\begin{aligned} \ln\frac{S_{t+1}}{S_t} &= \alpha_0 + \alpha_1\sigma_t^2 + \sigma_t\varepsilon_{t+1} \\ \sigma_t^2 &= \beta_0 + \beta_1\sigma_{t-1}^2 + \beta_2\sigma_{t-1}^2\max(0,-\varepsilon_t)^2 + \beta_3\sigma_{t-1}^2\varepsilon_t^2 \end{aligned} \tag{3}$$

Since the GARCH model has a time-varying volatility process, it is capable of displaying the kind of excess kurtosis found in the Cephalon's returns.

[2] See Melino & Turnbull (1990), Gallant, Hsieh, & Tauchen (1994), Harvey, Ruiz, & Shephard (1994), Danielsson (1994), and Jacquier, Polson, & Rossi (1994) for examples of these estimation methods in the context of stochastic volatility models.

The GJR GARCH(1,1) model differs from the standard GARCH(1,1) model due to the addition of the term $\beta_2\sigma_{t-1}^2 \max(0,-\varepsilon_t)^2$. This term allows for asymmetric volatility shocks, i.e., negative shocks tend to increase volatility more than positive shocks. This allows us to capture the leverage effect that has been observed in stock market data by Black (1976) and many others. This asymmetric volatility impact causes the conditional distribution in the GJR GARCH model to display skewness. Finally, by adding a variance term, $\alpha_1\sigma_t^2$, to the return process, we allow for a time-varying mean as well. The conditional mean in this case is linear in the conditional variance.

Even though the GARCH model above incorporates the non-normal features we observe in Cephalon's returns, we need to show that the GARCH model approximates some form of the stochastic volatility model posed above. To do this, we informally derive the continuous-time limit of the GARCH process.[3] Since we will be taking the limit as the time interval shrinks, we will rewrite the GARCH process in a way such that it explicitly accounts for the length of the time interval and such that the limiting drifts and diffusions of the continuous-time processes exist.

$$\begin{aligned}\ln\frac{S_{t+h}}{S_t} &= \alpha_0 h + \alpha_1\sigma_t^2 h + \sigma_t\sqrt{h}\varepsilon_{t+1} \\ \sigma_t^2 &= \beta_0 h + \beta_1\sigma_{t-h}^2 h + \beta_2\sigma_{t-h}^2 h\max(0,-\varepsilon_t)^2 + \beta_3\sigma_{t-h}^2 h\varepsilon_t^2 \qquad (4)\end{aligned}$$

where h is the time interval. Therefore, the trading period, T, is split up into $\frac{T}{h} = n$ trading intervals. With this definition, the conditional means and variances of the two processes can be calculated. The conditional means are given by

$$\begin{aligned}E_t[\ln S_{t+h} - \ln S_t] &= (\alpha_0 + \alpha_1\sigma_t^2)h \\ E_t[\sigma_t^2 - \sigma_{t-h}^2] &= [\beta_0 + (\beta_1 + \frac{1}{2}\beta_2 + \beta_3 - 1)\sigma_{t-h}^2]h\end{aligned}$$

while the conditional variances and covariance are given by

$$\begin{aligned}V_t[\ln S_{t+h} - \ln S_t] &= \sigma_t^2 h \\ V_t[\sigma_t^2 - \sigma_{t-h}^2] &= (\frac{1}{4}\beta_2^2 + 2\beta_2\beta_3 + \frac{1}{2}\beta_3^2)\sigma_{t-h}^4 h \\ Cov[(\ln S_{t+h} - \ln S_t)(\sigma_t^2 - \sigma_{t-h}^2)] &= -\frac{2}{\sqrt{2\pi}}\beta_2\sigma_{t-h}^3\end{aligned}$$

[3] See Nelson (1990) for a formal derivation for ARCH processes.

Therefore, as we take the limit as $h \to 0$ of (4), we get the following continuous-time process:

$$\frac{dS_t}{S_t} = [a_0 + a_1\sigma_t^2]\,dt + \sigma_t\,dW_S$$

$$d\sigma_t^2 = b_0[b_1 - \sigma_{t-h}^2]\,dt + \sigma_t^2\sqrt{\frac{1}{4}\beta_2^2 + 2\beta_2\beta_3 + \frac{1}{2}\beta_3^2}dW_\sigma$$

where

$$a_0 = \alpha_0$$

$$a_1 = \alpha_1 + \frac{1}{2}$$

$$b_0 = 1 - \beta_1 - \frac{1}{2}\beta_2 - \beta_3$$

$$b_1 = \frac{\beta_0}{1 - \beta_1 - \frac{1}{2}\beta_2 - \beta_3}$$

$$b_2 = \sqrt{\frac{1}{4}\beta_2^2 + 2\beta_2\beta_3 + \frac{1}{2}\beta_3^2}$$

and W_S and W_σ are Wiener processes with a constant correlation ρ given by

$$\rho = -\frac{2\beta_2}{\sqrt{2\pi\left(\frac{1}{4}\beta_2^2 + 2\beta_2\beta_3 + \frac{1}{2}\beta_3^2\right)}}$$

Thus, the continuous-time GJR GARCH(1,1)-in-mean process for the stock converges in distribution to the stochastic volatility process given in (2). While the one-period ahead conditional volatility in this GARCH model is deterministic, prices under this model converge to prices for the purely stochastic volatility model in (2) as the time interval becomes small, and consequently the prices of any European contingent claims written on a stock governed by these GARCH dynamics converge in distribution to the prices of similar claims written on the continuous-time stochastic volatility process. For daily data, these price differences will be insignificant.

Parameter estimates for the GARCH model using Cephalon's daily stock returns from January 1996 to May 1997 are given in Table 5. Most of the volatility parameters are found to be statistically significant, indicating the appropriateness of the GARCH model. In addition, the Kolmogorov-Smirnov D-statistic drops to .07 on the residuals, indicating that the residuals display a much better fit with a normal distribution. The hypothesis of normality can no longer be rejected at the 1% level as before.

A.2 Risk-Neutral GJR GARCH Process

In order to price the Cephalon warrants, the stochastic process for the stock must be derived under the martingale measure, $\tilde{P}$, given that under the actual measure, P, it is governed by the GJR GARCH(1,1)-M process.[4] One consequence of using a GARCH model for the underlying stock price process is that the pricing of contingent claims is no longer preference-free. Therefore, we start off by defining the pricing kernel.[5] Let ξ_t represent the pricing kernel in the economy. The pricing kernel simply represents the intertemporal marginal rate of substitution. The evolution of the pricing kernel is defined as follows:

$$\frac{\xi_{t+1}}{\xi_t} = \exp\left[-r - \frac{1}{2}\phi_{t+1}^2 - \phi_{t+1}\varepsilon_{t+1}\right] \tag{5}$$

The variable ϕ_t is a time-varying function that determines the market price of risk in the economy. ϕ_t is determined as a result of equilibrium given a set of supply and demand functions in an economy. If ϕ_t is known, then the Radon-Nikodym theorem may be used to determine the martingale measure in the economy. Suppose that agents' beliefs in the economy are captured by the probability space $(\Omega, \mathcal{F}, P)$ and $\omega \in \Omega$. Then martingale measure, $\tilde{P}$, is related to P by

$$\tilde{P}(A) = \sum_{\Omega} 1_{\{\omega \in A\}} \eta_t P(\Delta\omega)$$

where the Radon-Nikodym derivative η_t is given by the expression

$$\eta_T = \exp\left[\sum_{t=0}^{T} -\frac{1}{2}\phi_{t+1}^2 - \phi_{t+1}\varepsilon_{t+1}\right] \qquad A \in \mathcal{F}$$

[4] Amin & Ng (1993) study the risk neutral process for an ARCH stock price process, while Duan (1995) analyzes the risk neutral process for a GARCH(p,q) process.

[5] The pricing kernel, or marginal rate of substitution, is needed here because we are undertaking an equilibrium pricing model in an incomplete market. An alternative to this approach is the no-arbitrage model, which attempts to match a cross-section of option prices (see, for example, Rubinstein (1994), Derman & Kani (1994), or Dupire (1994)). For the no-arbitrage approach to work well, however, a sufficiently large cross-section of options maturing on the same date is necessary. Such a cross-section is not available on Cephalon stock.

Because ξ_t represents the marginal rate of substitution in the economy, the price at time t of a stock is related to the time $t+1$ price of the stock by the standard Euler condition

$$S_t = E_t[\frac{\xi_{t+1}}{\xi_t} S_{t+1}]$$

where the expectation is taken with respect to the P measure. Substituting from (3) and (5), we can derive the market price of risk, ϕ_t, in terms of the parameters of the stock process.

$$\phi_t = \frac{\alpha_0 + (\alpha_1 + \frac{1}{2})\sigma_t^2 - r}{\sigma_t} \tag{6}$$

Now, we can use a discrete-time version of Girsanov's theorem to relate a sequence of standard normal random variables under the $\tilde{P}$ measure to a set under the P measure. Define $\tilde{\varepsilon}_t$ to be a standard Normal random variable under $\tilde{P}$. Then $\tilde{\varepsilon}_t$ is related to ε_t by the relationship

$$\tilde{\varepsilon}_t = \varepsilon_t + \phi_t$$

We can substitute from this expression into (3) to derive the stock price process under the martingale measure

$$\begin{aligned} \ln \frac{S_{t+1}}{S_t} &= r + \frac{1}{2}\sigma_t^2 + \sigma_t \tilde{\varepsilon}_{t+1} \\ \sigma_t^2 &= \beta_0 + \beta_1 \sigma_{t-1}^2 + \beta_2 \sigma_{t-1}^2 \max(0, \phi_t - \tilde{\varepsilon}_t)^2 + \beta_3 \sigma_{t-1}^2 (\tilde{\varepsilon}_t - \phi_t)^2 \end{aligned} \tag{7}$$

where ϕ_t is given by (6). Note that the drift terms α_0 and α_1 are both present in the risk neutral process for the stock price and therefore will also be present in the option pricing formula. The implication of this is that, unlike with the Black-Scholes/Merton pricing formula, the drift of the stock price process enters into the option pricing formula. This dependence is due to the non-Markov nature of the GARCH process.

As noted earlier, the term ϕ_t can be thought of as the market price of risk at time t. Therefore, another crucial difference between this setup and that with geometric Brownian motion for the underlying is that this setup includes a time varying risk premium.

A.3 GARCH-Jump Process

Before we can price the warrants, the issue of how the FDA advisory committee's recommendation will impact the stock price needs to be considered. The announcement of this recommendation represents the sudden release of extremely relevant information to the market and therefore should have a large impact on the valuation of Cephalon's stock as well as its volatility level. The GARCH model we have constructed does not adequately capture this particular shock. To this end, we add a one-point jump term to the stochastic processes for the stock price and volatility. The complete stochastic process for the stock under the martingale measure is therefore given by the Jump GARCH process

$$\begin{aligned} \ln \frac{S_{t+1}}{S_t} &= r - \frac{1}{2}\sigma_t^2 + \sigma_t \varepsilon_{t+1} + J1_{\{t=t^*\}} \\ \sigma_t^2 &= \beta_0 + \beta_1 \sigma_{t-1}^2 + \beta_2 \sigma_{t-1}^2 \max(0, \phi_t - \tilde{\varepsilon}_t)^2 + \beta_3 \sigma_{t-1}^2 (\tilde{\varepsilon}_t - \phi_t)^2 + j1_{\{t \geq t^*\}} \end{aligned} \tag{8}$$

The jump term $1_{\{t=t^*\}}$ on the stock price reflects the large impact that the FDA committee's recommendation will have on the stock price. The jump term has a value of 0, except at time $t = t^*$, when the FDA announcement is made. At this time, the Bernoulli random variable, J, which reflects the magnitude of the jump, takes on a value J_u with probability p or J_d with probability $1 - p$.[6]

In addition, the jump term $1_{\{t \geq t^*\}}$ on the volatility process indicates that the information released will change the unconditional mean of the firm's volatility process. This jump term takes on a value of 0 until time $t = t^*$, at which point it takes on a value of 1 and stays at that value thereafter. The jump magnitude, j, is determined at time $t = t^*$ by a Bernoulli distribution. It takes on a value of j_u with probability p or j_d with probability $1 - p$. The value of j then stays the same thereafter. Thus, the unconditional mean of Cephalon's stock variance is altered from $\frac{\beta_0}{1-\beta_1-\frac{1}{2}\beta_2-\beta_3}$ to $\frac{\beta_0+j}{1-\beta_1-\frac{1}{2}\beta_2-\beta_3}$ at time t^*.

Estimation of the jump parameters cannot be accomplished by using the historical time series of the stock price since the jump term is not present in

[6] Note that these are risk-neutral quantities only and should not be interpreted as the actual parameters governing the jump process.

this series.[7] Therefore, to estimate the jump parameters, we rely on the prices of currently traded options on Cephalon's stock. If these options mature after the date of the FDA committee's decision, then the options incorporate the jump into their prices. Therefore, we estimate the jump parameters by fitting our option pricing model to cross-sectional data on the prices of Cephalon options maturing in August. The pricing model utilizes Monte Carlo simulation with a control variate for variance reduction. The time interval used in the model is daily. The upward jump magnitudes, J_u and j_u, are estimated to be 1.19 and 0.17, respectively, on May 7, while the downward jump magnitudes, J_d and j_d, are estimated to be 0.64 and 0.25, respectively. We also estimated these quantity one month prior, on April 8, using May options. Since no substantial news was released between the two dates regarding the probability of approval of Myotrophin, we would not expect the jump parameters to be significantly different from each other. This is confirmed as J_u and j_u, for example, are estimated to be 1.23 and 0.18, respectively.

A.4 Dilution Effect of Warrants

The final valuation of the Cephalon options also needs to account for the dilution effect caused by the warrants. In the case of standard warrants, exercising the warrants increases the number of shares of the firm outstanding. Therefore, exercise of the warrants means that the firm's profits are spread out over a larger number of shares, thereby decreasing the value of each share. In Cephalon's case, the dilution effect is caused by Cephalon itself when it exercises the options and thereby buys back its own stock. Therefore, one key difference between Cephalon's warrants and standard warrants is that the number of shares of the firm outstanding after the transaction decreases as a result of exercise. Secondly, unlike typical stock buybacks, upon exercise Cephalon will pay the exercise price of \$21.50 per share for stock that has a value higher than \$21.50.[8] Therefore, Cephalon has essentially underpaid for an asset, and the resulting value-added from this underpayment accrues

[7] Actually, it can be argued that the market knows the presence of the future jump shocks and therefore incorporates it into Cephalon's stock price and volatility. However, without a good model for valuing the stock itself, attempting to estimate the jump terms from the stock price series is beyond the scope of this paper.

[8] After all, Cephalon will only exercise the warrants if the stock has a value higher than the exercise price at the maturity date.

to those owning shares in the firm. This serves to enhance the value of all of Cephalon's outstanding shares, as well as shares purchased by Cephalon. As a result, the dilution effect for these warrants works in the opposite direction to that of typical warrants. The dilution effect of Cephalon's warrants will add value if the options are exercised.

A.5 Final Valuation

With all of the parameters estimated for the jump-GARCH model, we can now price the Cephalon warrants. The pricing model needs to incorporate three non-standard features of the warrants. First, the payoff on the warrant at expiration is determined by averaging the underlying over the previous twenty days and subtracting off the strike. Second, a cap of $39.50 is placed on this average. Thus, these warrants are essentially capped Asian options. Third, the warrants are exercised by the company against its own stock, so there is a negative dilution effect if the warrants are exercised. The Monte Carlo pricing model used earlier to estimate the jump parameters is modified to account for all of these features.

The price of the Cephalon warrants is calculated to be $3.48 per option.[9] As expected, the cap feature has the biggest impact on the warrant price. Without the cap of $39.50 in place on the underlying, the price of the warrants would be $4.98 each. The averaging feature has an insignificant impact on the price because the averaging period is very short–only 20 days. The dilution effect is substantial, adding approximately $.13 to the price of the option. As mentioned above, the dilution effect adds value to the warrant because if the firm exercises the option, it pays $21.50 per share for 2.5 million shares that have a higher value. This enhances the value of the shares purchased.

As indicated in the text, the warrant price derived here differs significantly from the price obtained by simply using the Black-Scholes/Merton model naively. Because the model we have used captures much of the complexity

[9] In running the Monte Carlo simulation model, the time interval used is daily, and 200,000 simulations are used to obtain prices. The underlying price is $19.85, which is calculated as in Shimko (1993) by using currently traded August puts and calls and finding the underlying price that best fits with put-call parity. Unlike Shimko (1993), however, the interest rate is not calculated through this method, but instead, the 6 month yield of 5.5% per annum is used. Finally, the initial volatility is calculated from the estimates of the GARCH model to be 5.3% per day on May 7. The estimated upward jump magnitude, j, is .307, with a corresponding jump probability of 42.4%, which were calculated as described above.

of the transaction, as well as the nonlinearities in the data, we feel this price discrepancy is an indication of the error produced when using the Black-Scholes/Merton model in cases where its underlying assumptions are clearly not met. When such nonlinearities as stochastic volatility and the one-point jump process are present, it is important that they be incorporated into pricing models.

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