Stock market valuation of R&D – Role of Contagion Shocks

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Abstract

We investigate the nature of contagion shocks in hi-tech R&D intensive industries and evaluate their impact on firm and industry level R&D. We distinguish the risks arising from such contagion shocks as different from the two commonly studied risks on R&D. The impact of contagion shocks on R&D has not been studied so far to our knowledge. We find that such shocks are numerous in all hi-tech sectors. Financial and trade reports have claimed that these shocks are contagious, recurrent and adversely affect R&D. We formulate a model to explain how contagion shocks evolve and trace their characteristics. Our model predicts that these shocks will be frequent, highly localized and affects future R&D expenditure by firms. We also suggest that firms with a higher R&D intensity suffer a greater adverse impact. We draw out testable hypotheses from our model in the context of pharmaceutical industry which is ranked as highly R&D intensive. We empirically test our hypotheses on a sample of all pharmaceutical firms and use the recent withdrawal of Vioxx by Merck as our market contagion event. The empirical tests confirm the predictions of our model. Our model and the findings have important policy implications for the R&D intensive industries. We suggest that policy measures to simplify the legal framework on tort litigation and measures to foster industry alliances will mitigate the impact of contagion shocks and enhance R&D.

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Stock market valuation of R&D – Role of Contagion shocks

We investigate the sudden, unpredictable shocks encountered in R&D intensive industries and their adverse impact on subsequent R&D outlays by firms in that industry. We term these shocks as contagion shocks.[2] We suggest that the risks arising from contagion shocks are different from two other types risks on R&D studied in the literature. We develop a model that explains the evolution of contagion shocks and their characteristics. Our focus is on how such shocks impact stock market valuation of R&D intensive firms on the one hand and on the decision to invest in R&D projects by the firms concerned on the other. To our knowledge the impact of risks associated with such shocks on R&D has not been examined so far and ours is the first effort in this area. We distinguish the risks from contagion shocks studied here from two other types of risks commonly seen in R&D literature. Current R&D literature examines two types of risks namely, the inherent misgivings about successes and failure of R&D projects and secondly, risks associated with changes in Government policy, technological obsolescence etc. Both these risks evolve over time unlike the risks associated with contagion shocks which are swift. R&D projects typically have a long gestation period and the extant literature and in particular the real options literature suggests that firms should reevaluate their R&D projects in multiple stages. Similarly the literature on valuation suggests techniques to value R&D and to calculate long term returns on firm R&D. However such tools are not very helpful in evaluating risks associated with sudden contagion shocks and firm valuation in the context of these shocks. We illustrate the importance of such shocks for R&D intensive firms, advance a methodology to study these shocks and appraise and measure their impact through an empirical study.

R&D and the risks associated with them have fascinated policy makers, practitioners, and academics alike. This is driven by the increasing importance of the Hi-tech sectors and firms which compete on superior research know-how. Investing in R&D is risky because of a long gestation period. Further, unlike investments in physical assets,

[2] We define a contagion shock as an unforeseen event that has a major adverse impact on one firm in an R&D intensive industry and triggers an industry wide impact. We further elaborate on and explain this phenomenon in the section on Model.

R&D expenditure is expensed thereby reducing current earnings reported to the shareholders. Despite these short-term disadvantages, the investment in R&D continues unabated.[3] As such, it is instructive to investigate in detail the various factors which encourage R&D, the risks associated with R&D and the stock market return on R&D expenditure. The study of these three aspects form an important part of R&D literature. We draw on the findings of this literature for our investigation of contagion shocks.

Studies on market returns for R&D expenditure in the near and long term are numerous. (Chan, Martin et al. 1990) and (Eberhart, Maxwell et al. 2004) find that R&D spending has a positive impact on long run stock market returns. (Doukas and Switzer 1992) find a significant correlation for firms in industries characterized by high seller concentration. (Chan, Lakonishok et al. 2001) find no significant correlation between R&D spending and stock market returns and comment that the market is apparently too pessimistic about beaten-down R&D-intensive technology stocks' prospects. (Sundaram, John et al. 1996) posit R&D as a strategic effort by a firm aimed at competition. They affirm that stock returns on R&D are significant when firm dominance and industry concentration are taken in to account.

The reverse relationship between changes in stock prices and the subsequent changes in R&D have also been investigated. (Durnev, Morck et al. 2004) find a link between changes in stock prices and Tobin's q and subsequent investment spending by firms. Their finding could be extended to subsequent R&D spending by firms.(Gugler, Mueller et al. 2004) specifically link Tobin's q and marginal Tobin's q to subsequent R&D spending.(Lichtenberg 2004) establishes a link between pharmaceutical stock prices and R&D during 1953 to 1996. These studies conclude that changes in stock prices bring about corresponding changes in subsequent R&D expenditures.

Overall the symbiotic link between R&D and stock prices is well accepted in the literature. If firms change their R&D spending, particularly in hi tech R&D intensive

[3] An account of the importance and growth of R&D expenditure is available at Deng, Z., B. Lev, et al. (1999). "Science and technology as predictors of stock performance." Financial Analysts Journal **55**(3): 20.

industries, it has subsequent impact on their stock prices and the market returns. Equally, changes in stock prices affect subsequent investments in R&D. This link has been used widely to investigate the impact of policy measures on R&D expenditure.

Stock prices of a given firm changes when firm specific characteristics and outlook change. When policy changes take place , they impact both stock prices and the R&D outlook of all the firms in the industry. Studies of such events in the domain of policy initiatives are fairly extensive.(Megna and Klock 1993) study the impact of policy changes in the semi conductor industry and their impact on stock prices and subsequent R&D efforts. (Lee and Hwang 2004) compare the role of Korean government in the Korean IT industry. (Ellison and Wallace 2001) have analyzed the impact of HSA 1991(Clinton Health plan) on subsequent pharmaceutical R&D. An extensive survey of such literature in pharmaceutical R&D can be found in a recent study by (Lichtenberg 2004) . He analyses the impact of policy pronouncements on innovation in the pharmaceutical industry. The study covers all major policy announcements including the1962 Kefauver-Harris Amendment, the1965 Social Security Amendments, the1984 Drug Price Competition and Patent Term Restriction Act, the 1992 Prescription Drug User Free Act and the 1993 Aborted Clinton Health Care Plan.

While there has been extensive studies of policy initiatives with regard to stock prices and R&D in hi-tech sectors, to our knowledge there have been no such studies with regard to contagion shocks which have an industry wide impact. Unlike policy initiatives which evolve over time with due notice to all participants, contagion shocks are swift and unforeseen. We believe that ours is the first study in this important area. In section 3, on “External Shocks in Hi-tech Sectors”, we examine the trade journals and news paper reports over the last ten years in the absence of previous academic literature on the subject. We find a number of such shock events and reasoned analysis by industry practitioners on their causes and possible impact.

We use the symbiotic link between stock prices and R&D which is well supported in the literature to examine the impact of contagion shocks on R&D expenditure. The extent of the increase or scaling back of R&D expenditure with changing stock prices would depend on the flexibility in R&D spending. R&D projects are long term and a firm typically has a bouquet of projects at various levels of fruition. The extent of scaling back or increase in R&D expenditure depends on the nature of this pipeline. This aspect is examined in greater detail in section 5 on hypotheses at hypotheses 3 and 4.

We develop a descriptive model to investigate how such shocks evolve and why they seem to be quite common in the hi-tech sectors. Our model has important predictions regarding stock price behavior, investor sophistication in the hi-Tech sectors, and the firm specific characteristics which drive subsequent changes in R&D. Our model predicts that investor sophistication will drive highly localized contagion effects with in the specific sector of the industry.

Based on our model, we derive four testable hypotheses. Our hypotheses predict that the contagion will be localized within a specific sub grouping of the industry rather than widespread across the industry. We also predict that R&D intensity of the firms rather than their current competitive position in the industry will drive the stock prices of the firms affected. We also predict that after an external shock, there will be a slowdown in R&D efforts and the extent of the slow down can be correlated to firm specific factors including the current nature of the R&D product portfolio under development.

We test our hypotheses on all listed firms in the pharmaceutical industry and select the withdrawal of Vioxx a blockbuster drug by Merck as our external shock event. We wish to stress that our methodology is not industry specific and can be applied to any other hi-tech industry. We choose the pharmaceutical industry as it is highly R&D intensive as shown by several studies such as (Chan, Lakonishok et al. 2001) and is therefore appropriate to test theories on R&D. There is a lot of public focus on pharmaceutical industry and extensive literature on pharmaceutical research is available. Drug R&D process is controlled by FDA (Food and Drug Administration) and the time and cost parameters are in the public domain. The industry has been around for a long time and historical data is available. Also the industry is highly regulated and the new products namely drugs are carefully monitored by the market and have attracted intense media attention and well researched trade reports. There have been numerous well argued opinions and debate in the trade journals about these market shocks which help us evaluate their impact. A similar study can be done for any of the hi-tech R&D intensive industry.

The empirical results are consistent with our predictions. We find that investors in the hi-tech industry are sophisticated and may also be conditioned by the frequent occurrence of external shock events in such industries. The contagion effects on share prices of firms are significant but highly localized. Other firms in different sub industry classifications are not similarly affected. We also find that the impact is governed more by perceived future risks on R&D investments and easily outweigh any short term competitive gains. Subsequent to the shock, firm level R&D declines and the extent of the decline is related to the nature of the firm R&D portfolio as predicted by us. Our model and its empirical support have important policy implications in the areas of alliances between pharma firms and contract research organizations (CROs) , simplifications in the legal system and the recent ideas about R&D consortium. We discuss the policy implications of our findings.

This paper makes a pioneering contribution in the study of contagion shocks and their role in shaping R&D. The role of these shocks in relation to R&D has not been studied so far. Through our model as well as empirical support from trade and newspaper reports, we establish that contagion shocks are quite common in hi-tech R&D intensive sectors. We also trace the characteristics and impact of these shocks.

The rest of the paper proceeds as follows. Section two presents the literature review. Section three surveys industry and finance reports and popular news over the last ten years and discusses the wide prevalence of sudden extreme shock events in high R&D intensive sectors and how they may impact R&D valuation and R&D spending. Section four develops the model. Section five develops the hypothesis. Section six explains the data and methodology. . Section seven discusses the findings and their implications. Section eight concludes.

Section 2: Literature Review:

2.1: Impact of R&D on Stock Prices

There have been several studies linking R&D spending to subsequent changes in stock prices. These findings are examined below. These studies however do not investigate if change in stock prices cause subsequent changes in R&D. (McConnell and Muscarella 1985) studied the announcement effects of all capital expenditures including R&D expenditure. They found a positive response from the market. (Doukas and Switzer 1992) investigate stock market's valuation of R&D expenditure plans of US firms. Their model relates expenditures on innovative activity to the market value of the firm. They tested it over a sample of firms that accounted for over 58% of company-funded R&D in the US in 1984. They did not find any significant correlation. However they noted that for firms in industries characterized by high (low) seller concentration, R&D expenditures were associated with significant positive (negative) excess stock returns. On the other hand (Chan, Martin et al. 1990) find a significant correlation between stock market returns and R&D expenditure.

Subsequently (Chan, Lakonishok et al. 2001) examined whether stock prices fully value firms' intangible assets, specifically research and development. Their sample consisted of six industries over a fifty year period. They also controlled for R&D capital. They found no significant correlation. They comment that the market is apparently too pessimistic about beaten-down R&D-intensive technology stocks' prospects. On the other hand, (Eberhart, Maxwell et al. 2004) examined the long-term performance of firms following (unexpected) research and development (R&D) increases. Their sample consisted of 8,313 cases during 1951-2001. They find a significant positive correlation.

There have also been several industry wide studies that have examined the role of R&D. (Megna and Klock 1993) study the semi conductor industry and find significant correlation between long term stock performance and investment in R&D. Similarly, (Ellison and Wallace 2001) find a significant correlation between R&D and stock returns in the pharmaceutical industry. On the other hand, (Klock and Megna 2000) find no significant correlation between R&D and long term stock performance in the wireless telecommunications industry. Similarly, (Christoffersen 2002) in her study of the textile industry finds that there is no correlation between R&D and stock performance. They also comment that Mann-Whitney rank test indicates firms that conduct R&D are not more profitable, than those that do not conduct R&D .(Sundaram, John et al. 1996) and (Prasad 2005) have attempted to explain R&D by positing it as a strategic effort by a firm aimed at competition. They analyze R&D spending by dominant and other firms. They conclude that industry concentration and firm dominance are important to explain stock market returns on R&D. Overall the link between R&D and stock prices is well accepted in the literature. If firms change their R&D spending, particularly in hi tech R&D intensive industries, it has subsequent impact on their stock prices and the market returns.

2.2: Impact of Stock Prices on R&D

Now we examine the reverse relationship between changes in stock prices and the subsequent changes in R&D. While studies in this area are not numerous it seems logical in view of the forgoing that when higher market valuations would enable a firm to spend more on R&D and firms will in fact spend on R&D and thereby improve their firm value. In an industry where R&D spending distinguishes the successful firms from the also rans, higher stock prices should result in a higher R&D outlay and a drop in stock prices should force a firm to scale down its R&D plans. (Durnev, Morck et al. 2004) find a link between changes in stock prices and Tobin's q and subsequent investment spending. This could be extended to R&D spending.(Gugler, Mueller et al. 2004) specifically link Tobin's q and marginal Tobin's q to subsequent R&D spending.(Lichtenberg 2004) has made an exhaustive study of forty six pharmaceutical firms over a period of 1953-1996 to establish a cross sectional link between pharmaceutical stock prices and R&D. There have been several studies which have examined the impact of Tobin's Q and Free cash flow on R&D. (Jose, Nichols et al. 1986) examined the impact of Tobin's Q and diversity on R&D. (Megna and Klock 1993) and (Lindenberg and Ross 1981) comment on the importance of Tobin's Q on R&D expenditure. (Megna and Klock 1993), find that Tobin's Q plays an important role on R&D in the wireless industry. (Youndt, Subramaniam et al. 2004) find a significant correlation between Tobin's Q and investment in R&D. The findings of changes in R&D because of changes in Tobin's Q can be extended to the changes in stock prices.

(Johnson 2003) and (MacKay 2003) among others have commented on the importance of capital structure in promoting investments in intangible assets in general and R&D in particular. This follows from the argument that investment in R&D is more risky and can not be easily collateralized to a lender. Unlike investments in physical assets, investments in R&D are to a large extent from own capital and they suffer when the firm valuation suffers. This lends further support to the link between changes in stock prices and the subsequent changes in R&D. The extent of the increase or scaling back of R&D outlay with changing stock prices would depend on the flexibility in R&D spending. R&D projects are long term and a firm typically has a bouquet of projects at various levels of fruition. The extent of scaling back in R&D in the near and long term depends on the nature of this pipeline. This aspect is examined in greater detail in section 5 hypotheses 3 and 4.

2.3: Impact of Government Policy Events on Stock Prices and R&D

Stock prices of a given firm changes when firm specific characteristics and outlook change. Often events occur which affect an entire industry. Such events cause stock prices of all firms across an industry to change. When such events affect a high tech R&D intensive sector, they impact both stock prices and the R&D outlook of all the firms in the sector. Government policy initiatives are a major source of such events. In regulated industries, changes in regulatory environment also cause such events. In either case these events occur gradually over an extended period of time and do not take the players by surprise. Studies of such events are fairly common and wide-ranging.(Megna and Klock 1993) study the impact of policy changes in the semi conductor industry and their impact on stock prices and subsequent R&D efforts. (Lee and Hwang 2004) compare the role of Korean government in the Korean IT industry.

In the pharmaceutical industry the impact of policy initiatives on pharmaceutical R&D and the stock prices have been extensively studied. (Ellison and Wallace 2001) have analyzed the impact of HSA 1991(Clinton Health plan) An extensive survey of such literature can be found in a recent study by (Lichtenberg 2004) who analyses the impact of policy pronouncements on innovation in the pharmaceutical industry. It covers all major policy announcements including the1962 Kefauver-Harris Amendment, the1965 Social Security Amendments, the1984 Drug Price Competition and Patent Term Restriction Act, the 1992 Prescription Drug User Free Act and the 1993 Aborted Clinton Health Care Plan. These studies establish that policy changes in the R&D intensive sectors affect firm values and R&D.

2.4: Impact of Market contagion shocks on Stock Prices and R&D

While there has been extensive studies of event windows around policy initiatives, to our knowledge there have been no studies which have investigated other market events like product recall, sudden sweeping changes in technology, lawsuits and the like which affect an entire industry. We believe that ours is the first study in this important area. Unlike the policy changes, the market events are sudden and often unforeseen. In the following section, we show that such events are common, widespread and far reaching in most hi-tech R&D intensive sectors in general and the pharmaceutical industry in particular. We also show that such events can significantly affect stock prices and subsequent R&D by firms in the sector.

Section 3: External Shocks in Hi-tech Sectors

There are no known academic studies that evaluate the impact of external market shocks on R&D expenditure in the hi-tech industries. We therefore rely on trade journals and news paper reports to ascertain the nature and extent of such events. We also scrutinize the probable causes and impact of such events as offered by the practitioners. Thereafter we subject these observations and findings to academic rigor in the subsequent sections.

We first identify the R&D intensive hi-tech sectors to look for the prevalence of market contagion shocks. We follow the well known study by (Chan, Lakonishok et al. 2001), who classify the top seven R&D intensive sectors based on four measures of R&D intensity namely, R&D intensity to sales, R&D intensity to assets, R&D intensity to market capitalization and R&D intensity to profits. The industries identified by them are Computer software (SIC 737), Pharmaceuticals (SIC 283), Computers and office equipment (SIC 357), measuring Instruments (SIC 38), Electrical equipment (SIC 36), Communications (SIC 48) and Transportation equipment (SIC 37). We now look for market contagion events in these industries.

For our study of these contagion events in these sectors we make extensive use of Factiva and LexisNexis databases and look for industry specific events over the last ten years. In particular we look for product recalls, environmental shocks, new scientific discoveries etc. In every case, we seek support from financial papers and journals which report a contagion effect on the rest of the industry. Our findings are summarized in Table 1. We identify ninety eight significant contagion events over the last ten years. This translates to roughly one event every month which has an industry wide impact for that industry. We find that in all these industries there have been quite a few events which can be called defining moments for the industry as a whole at that time. In all these cases (for example, the problem faced by Sony copyright protected CD drive), it is noticed that these events happened suddenly with no advance warning. Except perhaps for a few insiders within the specific firm, industry is probably taken by surprise. Policy changes and other governmental interventions evolve gradually after due notice is given to all the participants. In contrast the contagion events under study here are in the nature of extreme shock events.

Table 1 summarizes the extent of contagion events in all the seven industries over the past ten years from 1996 till 2005. This is not claimed to be an exhaustive list. The number of events in our finding may depend on the position of the industry in popular perception, the nature of the products offered by the industry etc. Industries like software or pharmaceuticals are in the limelight because they offer products which affect the daily life of a vast majority of consumers. The table supports our stand that contagion events are by no means a rarity in R&D intensive sectors.

We now focus on the pharmaceutical sector and look for contagion events as perceived by the trade and financial press. The pharmaceutical sector is highly R&D intensive and has the second rank in R&D intensity as per (Chan, Lakonishok et al. 2001). The R&D process is highly regulated by FDA and is in the public domain. The industry is under public scrutiny for their manufactures of life saving drugs as well as the cost of drugs which are often higher in the domestic market as compared to imports. We identify thirty-five events which can be called contagion shocks over the past ten years. An illustrative list of twenty events is presented in Table 2, which have had contagion effects as per the informed opinion in the trade reports. Many of these involve well known drug firms like GSK, Pfizer, Pharmacia, Eli Lily and Bayer. As recently as June 2005, Eli-Lilly[4] offered to pay seven hundred million dollars in partial compensation to settle some of the lawsuits based on Zyprexa reclassification controversy. The Zyprexa episode happened in September 2003, almost one year before the Vioxx withdrawal. It will be instructive to subject all these events to rigorous event studies. However our purpose here is to illustrate that such events are quite wide spread and frequent in the pharmaceutical industry in particular and the hi-tech R&D intensive sector in general.

[4] Wall Street Journal 15 June 2005.

From the various candidate contagion events from the pharmaceutical industry described in Table 2, we choose the withdrawal of Vioxx by Merck as the contagion event for our study. In our assessment, this choice has several advantages. One of the conclusions from the study is likely to be on policy implications and for this a recent, major event is appropriate. Merck is a well known large sized firm which has met with a major shock and therefore a detailed analysis of the event is available in the trade and financial literature. Also the event is still unfolding, so there are fewer chances of our testable hypotheses being colored by an already existing data. As a matter of fact, our hypothesis regarding drop in subsequent R&D is yet to be tested on annual R&D data as it is still unfolding. We now test this hypothesis on quarterly data. We hope that a subsequent test with and confirmation by the annual R&D data will further lend support to our hypothesis. Similarly, we hope to follow this event through the next stages of court litigation, award of damages etc should there occur a sudden surprise event.

Table 3 lists the key event dates that accompanied the withdrawal of the controversial drug Vioxx. We have listed all major events up to December 2005 and hope to follow up on these events should any of them qualify as a sudden shock. It will be seen that ever since 2000 when the VIGOR study was published, there have been suspicions and apprehensions about Vioxx. This is within a year of the successful approval and launches of the drug in 1999.But the nebulous and complex nature of R&D for new drugs ensured that a clear cut analysis of VIGOR report was difficult. Even after the study, Merck claimed that there was no adverse side effect on Vioxx. FDA took over a year to study and analyze VIGOR report and then concluded that warning labels were sufficient. Meanwhile Merck began a three year study essentially to find additional uses for Vioxx but also to study possible adverse side effects. As a responsible corporate entity and also aware of the potential billion dollar law suits, it is unlikely that any firm would have continued to market a drug it was not confident about. We also find no evidence of any significant insider trading prior to September 30, the official date of withdrawal. This supports our view that these market contagion events by and large take the industry by surprise and are sudden, although it is possible to detect some prior signs after the event. As per the trade report all the events reported in Tables 1 and 2 qualify as contagion events. It is a moot point why such events take place with surprising regularity in the hi-tech sector. This aspect is discussed in detail in our descriptive model in the next section.

While analyzing the impact of withdrawal of Vioxx by Merck, there are several interesting and reasoned arguments by analysts. These deserve serious consideration as they emanate from people who have an intimate knowledge of the industry and the specific events. Most of the analysts agreed as early as September 30 that all pharmaceutical firms will be adversely affected and that this event was linked to and followed a long chain of recent drug withdrawals described in Table2. There was interesting speculation about whether firms like Pfizer which had a competing drug would benefit. Analysts also tried to reason out the adverse impact on other firms based on their R&D intensity or pipeline of drugs under research. Some of these observations are listed below. We formulate our hypothesis based on some of these comments and subject them to academic rigor.

Dow Jones Industry analyst surmised that [5]Merck's news has sent shares of most drug makers lower. She added that there has been a history over the past few years of major drugs being withdrawn under adverse publicity on safety considerations[6]. Merck news coming on top of previous news will push down pharma stock prices.

An analyst from Wall street journal[7] opined that Vioxx's removal from the market could be good news for Pfizer, because it has a drug celebrex that competes with Vioxx. However another analyst suggested [8]that Pfizer’s drug celebrex is similar to vioxx. Pfizer with similar drug is more affected than other Phrama companies. It is bad news for Pfizer.

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[5] Cynthia Schreiber , analyst , 30 September 2004, Dow Jones Commodity Wire

[6] Some major drug withdrawals are mentioned in Table 2.

[7] Mark Gongloff The Wall Street Journal 30 September 2004

[8] Joseph Schuman The Wall Street Journal 30 September 2004

It was felt that FDA would be under more pressure and Drug safety guidelines will be tougher. Some analysts[9] said that pharma companies planning to bring block buster drugs will be affected.

Industry watchers had speculated that Merck may have been interested in acquiring Schering-Plough, which co-markets the cholesterol drug Vytorin with Merck. Stock price outlook for Schering-Plough will be down[10]

Biotech firms will do well. Now they will gain the upper hand in negotiations with big pharma companies for joint ventures and collaborations.[11]

Small pharma firms which co-market drugs and ally themselves in various ways with big pharma firms will fare worse. But independent small pharma firms will do better.[12]

Firms like Johnson & Johnson which do not depend on block buster drugs will do well. Their values are not disturbed by anticipated tougher screening for new drugs.[13]

European firms are better placed than US firms. They have less dependence over the next four years on drugs in the pipeline.[14]

These discussions illustrate that the analysts were examining the withdrawal of Vioxx by Merck as an industry contagion rather than as a downfall for Merck and a gain for its competitors. The analysts also link this event to a long chain of previous contagion events. There is also an undercurrent of feeling that there will be more drug recalls in the future resulting in many more such contagion events. The subsequent sections on Model and Hypotheses attempt to draw on the previous academic literature as well as on the trade insight discussed here.

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[9] Crowell, Weedon & Co. analyst Doug Christopher.
[10] Deutsche Bank analyst Barbara Ryan
[11] John Borzilleri, Manager GRT Healthcare
[12] Tracey Boles, Knight Ridder 10 October 2004

[13] Louis Rukeyser's Wall Street
[14] Goldman Sachs press note

Section 4: Model

In this section, we investigate the reasons for the wide spread occurrence of external shocks in a hi-tech R&D intensive industry. We argue that the prevalence of external shocks and a wide ranging contagion based on external shocks is in the very nature of R&D intensive industries. To do so we derive a descriptive model for firm level R&D. Our model is based on Schumpeterian theories of innovation(Schumpeter, Alois. et al. 1989) and the theory of imperfect competition(Dixit and Stiglitz 1977; Dixit 1988). We construct the model by imposing a set of justifiable assumptions and examine the role of the firm, firm managers, industry network, and the investors through our model.

4.1: Model - Assumptions

R&D efforts require large outlays over a long period of time (Lev and Sougiannis 1996). At the end of these efforts, the results are uncertain. If an industry is fragmented with numerous small players, none of them can afford to take up costly R&D in a big way. This is the crux of the Schumpeterian argument that big firms in concentrated industries drive growth. On the other hand, the theory of imperfect competition and product differentiation [(Dixit and Stiglitz 1977; Dixit 1988)] postulates that innovation is driven by competition. So R&D increases with competition. Both these theories agree that within a given industry, bigger and dominant firms do more R&D and serve as benchmarks for other firms.

We formulate a descriptive model for R&D based on a harmonized reading of Schumpeterian theory of dominant firms doing maximum R&D and the theory of imperfect competition. Our model has four assumptions. Firstly, we assume based on Schumpeterian theory that the investment in R&D is risky and involves outlays over a long period. If R&D were not risky and can be done over a short period, there will be no major differences amongst firms in doing R&D. Every firm will carry out R&D based on its own economic analysis and quite independent of other firms. However the risks involved in innovation are qualitatively different from the risks that accompany other managerial decisions. Secondly, we assume that all the firms in the industry compete on the basis of superior products resulting from R&D rather than on price. In some industries, especially mature industries price considerations are more important to the customer than new improved products. In such industries firms may not compete on the basis of innovation and R&D is not a must to stay in business. Thirdly, we assume that the superiority of the product is known to the consumer and she is willing to pay a higher price if necessary for the superior product. We thus assume away the lemons problem. If lemons problem were to exist, branding, advertising and reputation building become as important as innovation and superior products. Based on the foregoing, we illustrate in the next sub section that the motivation for R&D is the threat of going out of business. It can be seen that these assumptions are reasonable with regard to the pharmaceutical industry tested in this study and for Hi-Tech/R&D intensive industries in general. Consumers buy the most effective medicine rather than the cheapest medicine with the exception of generics. There is no lemons problem because of the certification by FDA and the physician. Pharmaceutical R&D is expensive and takes a long time(Lev and Sougiannis 1996). Pharmaceutical firms barring a sub category of generic firms compete on the basis of their innovation.

4.2: Model – Role of firm and Industry network.

We now trace the evolution of R&D efforts in a hypothetical Hi-Tech industry which satisfies the four assumptions mentioned above. A schematic representation of our model is given in Table 4. In the first stage, there is only one firm in the industry. Such a firm faces no threat of a superior product from a competitor and has no incentive to do risky R&D. The R&D efforts will be minimal and may focus on cost reduction and R&D projects that are relatively less risky and bring about marginal improvements in the products offered to the consumer. As competitors arrive, all the firms are threatened with loss of their business when their competitor launches superior products. So they all start investing in risky R&D. The motivation for R&D arises out of the fear of going out of business. The smaller firms are more vulnerable and closely monitor their bigger rivals and carry out adequate R&D to stay in business. The bigger firms, although not as vulnerable as the smaller firms need to ensure that their nimble rivals do not wipe out some of their businesses.

Thus firms in hi-tech industries carry out R&D because they are forced to do so to stay in business and avoid a "business stealing"[15] by their competitors. The bigger and dominant firms lay down the benchmark and industry standards and others play a "catch on". All the firms in the industry feel a need to constantly monitor the trends and plan of their competitors through market intelligence. Based on these market inputs they curtail or expand their R&D expenditure plans (Danzon, Nicholson et al. 2003). Everybody needs to keep abreast of their competitors. This usually results in a well established industry net work, assortment of trade reports and journals, meetings and conferences all dedicated towards keeping all the players well informed of each other. Nevertheless specifics of R&D plans are kept highly confidential and there is an under current of the fear of the unknown amongst all players. At the slightest signal of danger, the players rush to take defensive action to protect their business. It can be seen that this is an ideal setting to cause a contagion. It can be further seen that these assumptions are reasonable with regard to the pharmaceutical industry tested in this study and for Hi-Tech/R&D intensive industries in general. Pharmaceutical firms base their R&D on industry R&D (Grabowski and Vernon 1987) and thus maintain a close watch on other players . They also maintain a close network through associations and conferences.

4.3: Model – Role of Investors

We now examine the profile and the role of the investors in hi-tech sectors. These investors are willing to take risk by investing in R&D and are usually well aware of the risks associated with R&D(Chauvin and Hirschey 1993). The investors are also aware of the need for constant monitoring of their investments in R&D intensive stocks through market intelligence and expert advice. (Garlappi 2004) points out that volatility can

[15] Schumpeter, J. Alois., et al. (1989). "Essays : on entrepreneurs, innovations, business cycles, and the evolution of capitalism / Joseph A. Schumpeter ;edited by Richard V. Clemence ; with a new introduction by Richard Swedberg." New Brunswick, N.J., U.S.A. : Transaction Publishers,c1989.

increase threefold in a highly competitive R&D intensive industry as compared to a collusive industry. The investors are sophisticated and monitor their investments. They may time the market but do not resort to panic selling. They are also aware of the close networking in the industry and the high probability of a contagion. They have also been conditioned by the break out of similar events in the past. Investors know that when any one firm is affected all other firms in the localized industry subgroup take "damage control" action and all the firms in that sub group of industry adjust their R&D to a new industry level R&D. This ensures that the outbreak of an external shock results in a contagion in the stock market. It also ensures that the contagion is selective and localized as opposed to any panic selling.

4.4: Model – External Shocks Triggers

Hi-tech, R&D intensive sectors are characterized by a high level of innovation, rapid changes in product offerings and a high component of intangible R&D assets in the form of know-how. Unlike physical plant and machinery, R&D know how can be wiped out swiftly with the offering of next generation products and these happen regularly as the industry keeps generating new products. To the extent, the changes can be anticipated there is a planned obsolescence and write off. But it is in the very nature of these industries that unexpected developments will take place and wipe out the competition. Equally, when new products and services are continuously brought in to the market place there is a rush to be a pioneer and be ahead of a possible scoop by competition. In such a scenario mistakes are inevitable. Such mistakes result in costly lawsuits and product recalls. If the industry is regulated it results in added litigation for violation of laws. Higher the R&D intensity, faster the growth and keener the competition, the more likely and frequent will be the external shocks and contagion events.

To sum up, these shocks are inevitable in any hi-tech R&D intensive sector. The external shocks will be more likely and more frequent with higher R&D intensity, faster growth and keener competition. These shocks are exacerbated by the firms because of their close networking and underlying sense of fear. The resultant effect is further enhanced by the investors in these sectors who are sophisticated and are conditioned by previous external shocks. A schematic view of the model is presented in Table 4.

Section 5: Hypotheses:

In this section we derive the testable hypotheses based on our model for extreme external shocks. We examine the pharmaceutical industry and the withdrawal of Vioxx by Merck to derive our testable hypotheses. Pharmaceutical industry is selected as it is highly R&D intensive [(Chan, Lakonishok et al. 2001)] and is suitable to test theories on R&D. There is extensive literature on R&D in pharmaceutical research. There has been extensive study of R&D capital in this industry as noted by (Grabowski and Vernon 2000) .Information on R&D gestation periods and R&D capital are regularly updated in the Pharma yearbooks. Also the industry is highly regulated and the new products namely drugs are carefully monitored by the market. As shown in section 3, there have been well documented withdrawals of block buster drugs which have attracted intense media attention. There have been numerous well argued opinions and debate in the trade journals about these events which help us evaluate the impact of these events. We take the withdrawal of the drug vioxx by Merck as the external shock event as it s recent and has received a wide and informed coverage. It is however emphasized that similar investigation can be conducted for any other industry or groups of firms. A similar study can be done for any of the hi-tech R&D intensive industry.

Our model predicts that external shocks are common in R&D intensive industries and affect the firm valuation, cost of R&D and the subsequent capital expenditure committed by the firms on R&D. Investments in R&D are risky and require sophistication on the part of the firm investing in R&D as well as on the part of the investors investing in the firm. We have predicted that the market will be well aware of the distinctions amongst industry sub groups. Firms in the industry not in the same industry sub group will not be affected as much as the relevant sub group.

This leads to our first hypothesis.

Hypothesis 1*: In the aftermath of withdrawal of Vioxx, contagion effects would be significant and localized on firms in a similar market as Merck but other pharmaceutical firms will not suffer a significant contagion impact.*

Within the industry subgroup, there may be firms which are specially linked to the firm suffering the shock. Some of the firms may be direct competitors which may hope to gain from the episode. Others may have a close business connection with the firm suffering the shock and may be hurt more. Our model predicts that the contagion effect and the additional risks and costs for R&D will prevail over any short term benefits. However, firms which are closely associated with the firm suffering the shock, may suffer more than other firms as the firm needs to do more damage control than other firms in the industry and the sophisticated investors are aware of this situation. Pfizer and Schering have a closer connection with Merck as compared to other firms in the industry sub group. Pfizer markets a drug celebrex that competes with Vioxx. Schering and Merck have a marketing alliance[16]. So overall Pfizer may benefit due to the competitor's loss or may be hurt by a contagion because of the perceived impact on future R&D costs[17].It will be interesting to examine which of the two effects predominate. Our model predicts that R&D forms a major aspect of pharmaceutical firms. Any adverse costs on doing R&D will outweigh any short-term advantages due to a competing product in the market place. An analogy can be drawn that firms do R&D for their long term benefits not withstanding the short term adverse effects of lower profits. In R&D intensive industries, we expect the long term impact to prevail. We therefore expect a significant negative abnormal return on other firms closely allied with Merck. In case of Schering the initial impact may be higher but overall the loss will be due to the contagion effect and the firm specific factors for Schering.

[16] Please refer to Footnote 7
[17] Please refer to footnotes 4 and 5.

This leads us to our second hypothesis.

> ***Hypothesis 2:*** *The withdrawal of Vioxx and its adverse effect on Merck would induce significant adverse abnormal returns on other pharmaceutical firms closely connected with it. Any short term benefits to firms with competing products will be outweighed by the anticipated adverse long term impacts on future R&D costs.*

Among the firms which are affected, the extent of impact will vary with firm specific characteristics. In particular, we expect that maximum impact will be felt by firms with the highest R&D intensity as these firms will face the maximum impact of any adverse R&D risk. Generic drug firms which have very little R&D will face lower impact. Also among R&D intensive firms, those which have a larger number of R&D products pending approval for market will face a more adverse impact than those with few immediate products in the pipeline. It seems reasonable that longer the time taken for fruition for a product in the pipeline, the more will be the perceived risk of R&D.

To test this hypothesis, we need proxies for R&D intensity as also a proxy for the R&D product pipeline. For R&D intensity, the available literature suggests three proxies. Chan et al (Chan, Lakonishok et al. 2001) , suggest R&D capital which is an equally depreciated capitalized value of R&D over the last five years. A measure given by the current R&D spending divided by the current sales is suggested by (Szewczyk, Tsetsekos et al. 1996). The literature on pharmaceutical R&D notes the increasing number of CROs (Contract Research Organizations) in the industry. These CROs carry out R&D either on subcontract or for development and subsequent sales to other pharmaceutical companies. (Danzon, Nicholson et al. 2003) find that these firms do not have significant sales of pharmaceutical products but have significant assets in place. Calculating R&D intensity for such firms using sales will not be meaningful. Leaving out such firms in a study on R&D will result in erroneous conclusions. R&D intensity calculated based on R&D expenditure to total assets can capture these firms. We suggest that R&D capital is a more appropriate measure for longer term studies while asset intensity of R&D is a better measure for near term studies. In this study we use R&D as a percentage of total assets as a proxy for R&D intensity.

We also need a measure for the R&D products in pipeline and the likely time the various products in the pipeline will take to hit the market. We suggest two proxies to measure this pipeline. First ,following (Jose, Nichols et al. 1986; Megna and Klock 1993), we suggest that Tobin's Q measures the R&D potential of the firm. The R&D portfolio of a firm consists of both existing products being currently marketed and future products which will hit the market later. The existing products also have real assets in the form of plant and working capital to back them and have also generated past cash flows which have enhanced the book value. The future products have no such real assets allocated to them and have not generated prior positive cash flows.. Therefore other things being the same a larger Tobin' q would imply a larger measure of future products from the R&D pipeline as compared to the currently marketed products. Such firms with a higher Tobin' Q and a higher proportion of future products are more likely to be impacted more by such external shocks. As a second measure we use the liquid assets maintained by the firms. We note the finding by (Johnson 2003) that firms are more vulnerable in capitalizing on growth opportunities when they have less liquidity. Also firms which have accumulated liquidity may probably be planning for long term R&D projects.

This leads us to our third hypothesis

> ***Hypothesis 3:*** *Other things being same, firms with higher R&D intensity, firms with higher Tobin' Q and higher liquidity will be more adversely affected and will show a more adverse abnormal return when a contagion shock takes place.*

We now argue that firms which have been adversely affected by the external shock will respond by lowering their sights on future R&D expenditure. This should show up in terms of reduced R&D intensity in the subsequent period. Studies that have quantified the adverse impact of external events on R&D are known in the pharmaceutical literature. Mention may be made of (Grabowski and Vernon 2000) and (Ellison and Wallace 2001) which have examined the impact of policy pronouncements on R&D in the industry. Our study, the first to investigate the impact on R&D due to sudden external shocks follows the event study methodology but it is reasonable to expect a decline in R&D. Again following our rationale in formulating the third hypothesis, firms with a higher R&D intensity, higher Tobin's Q and a greater liquidity will be more affected and will suffer a greater reduction in R&D intensity. Not much time has elapsed after Merck announced its decision to withdraw Vioxx from the market in September 2004. Subsequent R&D expenditures that is the R&D expenditure for the year 2005 are not yet available. Even the R&D expenditure for the first two quarters of 2005 is available for only about twenty firms. We therefore compare the R&D intensity of for the first quarter of 2005 against the R&D intensity of the same firms for the first quarter of 2004, which is a comparison of the intensity before and after the event.[18]

This leads us to our fourth hypothesis.

> ***Hypothesis 4:*** *R&D intensity of the firms would decline after the external shock. The decline would be more pronounced in the firms with a higher R&D intensity, larger Tobin Q and higher liquidity.*

Section 6: Data and Methodology

We use firm level and industry data from pharmaceutical industry to test our hypotheses. Pharmaceutical industry is selected as it is highly R&D intensive [(Chan, Lakonishok et al. 2001)] and is suitable to test theories on R&D. There is extensive

[18] By March 2006, the annual R&D data for 2005 should be available for most firms and the study will be updated based on the annual data.

literature on R&D in pharmaceutical research. There has been extensive study of R&D capital in this industry as noted by (Grabowski and Vernon 2000) .Information on R&D gestation periods and R&D capital are regularly updated in the Pharma yearbooks. Also the industry is highly regulated and the new products namely drugs are carefully monitored by the market. As shown in section 3, there have been well documented withdrawals of block buster drugs which have attracted intense media attention. There have been numerous well argued opinions and debate in the trade journals about these events which help us evaluate the impact of these events. We take the withdrawal of the drug vioxx by Merck as the external shock event. We wish to stress that the study is not industry specific. A similar study can be done for any of the hi-tech R&D intensive industry. As we have shown in sections 3 on trade reports and section 4 on our model, external shocks are expected to arise and do arise in such sectors.

We use share price movements in the market and well researched articles and news items from trade journals and news papers during September / December 2004 when the events pertaining to withdrawal of Vioxx took place. The key dates and the events around them are highlighted in Table 3. We investigate all pharmaceutical firms which were active at this time. This includes all listed pharmaceutical firms at that time in the SIC codes 2833 Medicinal Chemicals and Botanical Products, 2834 Pharmaceutical Preparations, 2835 In-Vitro and In-Vivo Diagnostic Substances (except in-vitro diagnostic) and in-Vitro and In-Vivo Diagnostic Substances (in-vitro diagnostic substances). We employ the financial and accounting data of these firms for the year 2004 and quarterly R&D data for the first quarter of 2004 and 2005 to analyze the abnormal returns of stock prices and relate it to the firm characteristics.

For analyzing the events and the opinions thereon expressed in the industry, we make use of Factiva and the LexisNexis databases. We use informed reports in all financial, trade journals and popular newspapers covered by these databases. We evaluate the trend of events and the various informed theories and assessments offered in the industry, trade and financial media to better formulate our model and hypotheses. We perused over 1500 clippings and reports during this period. A summary of our findings is given under “Section 3: External Shocks in Hi-tech Sectors” and under Tables 1 and 2 and 3.

We study the share prices and abnormal returns around the event date of 30th September 2005. For this we take stock price data from the Center for Research in Security Prices (CRSP). For accounting and financial data we use Standard and Poor’s Compustat database. To access some of the recent data, we supplement these sources with SEC filings and information disclosed in the respective firm website. The abnormal returns are calculated using Eventus software and we calculate abnormal returns using four benchmarks, namely “Market model – value weighted returns; “Market model – equally weighted returns; “Market adjusted model – value weighted returns; “Market adjusted model – equally weighted returns; The total number of firms under SIC sub codes 2833, 2834 and 2835 and covered by CRSP and Compustat add up to one hundred and twenty four firms and these firms constitute the sample of all pharmaceutical firms in our data set. The number of firms in the SIC subgroup 2834 is one hundred and six including Merck. To study the contagion effect, we exclude Merck and thus we have one hundred and five firms in this subgroup which constitute the firms in the same sub group as Merck. The summary statistics for these firms are given in Table 5.

To test our first hypothesis, we need a proxy for firms in the same market as Merck and other firms not in the similar market. We use the SIC subgroup codes as a proxy for firms operating in similar markets. We consider all firms in the SIC subgroup 2834 as firms operating in similar markets as Merck. Firms in the SIC subgroups 2833 and 2835 are reckoned as firms not in similar markets.

To test our second hypothesis, we need to identify firms which have competing products or other relationship with Merck. We identify these firms from product data literature and the comments in trade reports which we verify from company annual statements and other sources. We identify Pfizer and Schering Plough as firms of special interest under this category.

To test our third hypothesis, we need to further classify firms within SIC subgroup 2834 in terms of firm specific characteristics. We need proxies for R&D intensity, nature of the R&D portfolio pipeline and firm liquidity. We calculate R&D intensity as total R&D expenditure reported for the year as a percentage of the total assets of the firm following (Danzon, Nicholson et al. 2003). To measure the R&D portfolio pipeline, we use Tobin's Q. Both average as well as marginal Tobin's Q is cited in the literature. Following (Gugler, Mueller et al. 2004) , we use the average Tobin' q as more representative an indicator for R&D. Following (Johnson 2003), we measure liquidity as percentage liquid assets to the total assets.

To test our fourth hypothesis, we need proxies for decline in R&D intensity, nature of the R&D portfolio pipeline and firm liquidity. We calculate R&D intensity, liquidity and nature of the R&D portfolio pipeline the same way as in hypothesis 3. To measure the decline in R&D intensity, we need data of R&D expenditure after September 2004.The event is still recent and annual R&D spending for the immediate next year 2005 is not yet available. Our first effort was to compare the half yearly R&D expenditure for the years 2004 and 2005.using quarterly reports and company filings. But the data was inadequate as only twenty firms had reported the data. The quarterly reporting of R&D expenditure is not yet mandatory and the firms may choose not to disclose this information. We therefore compared the R&D expenditure for the first quarter of 2004 to available R&D expenditure for the first quarter of 2005 using quarterly data. Of our sample of one hundred and five firms we could gather these data only for seventy eight firms. Thus we test hypothesis four on a reduced sample of seventy eight firms. This will be updated when we are able to access annual R&D data for firms which are compulsorily disclosed. As of now, the reduced availability of firms in the sample may have a sample selectivity bias. That is firms which have scaled back R&D may choose not to report the data. If this were indeed the case, any finding of reduced R&D even with this sample will further bolster our contention.

The findings are discussed in the following section.

Section 7: Findings and their implications

7.1 Localized Nature of Contagion Events

The information presented in Tables 1 and 2 reveal the possibility of a large number of contagion events taking place in the hi-tech sector. The financial and trade analysts have discussed nearly a hundred such events in the last ten years. Even with respect to the event under study, namely the withdrawal of Vioxx by Merck, a majority of the analysts linked it to a large chain of similar events from the past and also predicted that more such events will take place in the future. It is therefore instructive to investigate the characteristics of these contagion events and how localized or wide spread they tend to be in their impact.

Table Six presents a graphic view of the cumulative abnormal returns over a sixty day window around the event period namely 30th September 2004. We calculate the cumulative abnormal returns under four models, namely "Market model – value weighted returns; "Market model – equally weighted returns; "Market adjusted model – value weighted returns; "Market adjusted model – equally weighted returns; from September 1, 2004 to October 31, 2004. The abnormal returns ware calculated for the individual SIC sub groups 2833 , 2834(except Merck), 2835 as well as for firms of interest namely Merck, Pfizer and Schering.

It may be clearly seen from Table 6, that firms in the SIC subgroups 2833 and 2835 did not suffer any significant contagion effects because of the withdrawal of Vioxx. As a matter of fact SIC sub group 2833 had a rising (positive) cumulative abnormal return and the cumulative abnormal returns continued to rise after the event date and no significant change in the returns is observed around the event date. SIC subgroup 2835 did not experience any significant cumulative abnormal return either favorable or adverse during this sixty day period. Also no significant changes are seen around the event date. At the end of the sixty day period there is small positive abnormal return. This can be contrasted with the huge adverse abnormal return noticed for SIC sub group 2834 to which Merck belongs.

In Tables 7 and 8 analyses of the abnormal returns around shorter windows is presented for SIC sub groupings 2833 and 2835. It is noticed that the "z" statistics are by and large not significant which further goes to support the view that the contagion was confined to firms in the SIC sub group 2834. In contrast we find in Table 9, which shows the analysis for SIC subgroup 2834 (except Merck), the "z" statistics especially under the two market adjusted models are all significant. It is also seen from Table 6, that there was a steady decline of cumulative abnormal returns for firms (other than Merck) under SIC sub code 2834. This further conforms to our model that the investors in these sectors are sophisticated and not prone to panic selling. Overall, the empirical results provide a strong support for our first hypothesis that the contagion events in the hi-tech sectors will be largely localized.

7.2 Effect of Contagion on Firms with special relationships

Industry and trade analysts[19], had indicated special relationship between Pfizer and Merck due to competing products and also between Schering and Merck because of a marketing alliance. Pfizer stood to gain as its product celebrex competed with Vioxx. Analysts debated and differed on whether overall Pfizer would gain or loose from the event in terms of market returns. Our model stresses that R&D plays a crucial role in the valuation of these forms and both the firms and the investors watch for the contagion effects and take corrective actions. It can be seen from Table 6, that Pfizer in spite of a short term competitive advantage suffered significant adverse abnormal returns. In fact the adverse abnormal returns for Pfizer were more than that for the SIC sub group 2834 (barring Merck). This could be linked to the higher R&D intensive nature of Pfizer as suggested in our third hypothesis. As expected by the analysts, Schering also suffered significant adverse abnormal returns. All the three firms Merck, Pfizer and Schering suffered adverse abnormal returns. As suggested by firm specific market conditions ,

[19] Please see foot notes 4, 5 and 7.

Merck had the maximum adverse returns followed by Schering and then Pfizer. The empirical results bear out hypothesis 2.

7.2 Effect of Contagion Related to Firms Specific Factors

Table 10 presents the regression results relating the cumulative abnormal returns for select windows against the R&D intensive nature of the firm and its R&D product portfolio as proxied by R&D intensity to assets, Tobin' Q and liquidity. Hypothesis 3 suggests that firms which are more R&D intensive, namely firms with higher R&D intensity, higher Tobin's Q and higher liquidity will be more adversely affected.

The results of the regressions fully bear out this hypothesis. The signs of all the coefficients are as per expectation that is the coefficients are negative. In regressions for nearly all the windows, liquidity our proxy for the nature of the R&D pipeline is highly significant. R&D intensity is also significant for several regressions. Tobin' Q is not significant although the sign for the coefficient is as predicted. As discussed, Tobin' Q captures the effect of both products being currently marketed as well as future products while liquidity captures the effect only of future products. Thus as expected, liquidity is a better indicator of adverse contagion. The results of the regressions lend strong confirmation of Hypothesis 3.

7.3 Impact of Contagion Related to Future R&D

Table 11 presents the results of the regression firm wise change in R&D from first quarter 2004 to first quarter 2005. We chose the comparison first quarter R&D as we could collect the information for eighty firms from our sample of one hundred and two firms barring Merck. In addition to the regression results, we would like to mention a few interesting observations. Overall the aggregate R&D expenditure in our sample fell by 11% in our sample of eighty firms. Also R&D expenditures of Pfizer fell by 32%, Eli Lily by 30 % and Wyeth by 14 % over the same quarter in the previous year. Our findings of a significant drop in R&D expenditure with a fall in market valuation is in line with the findings by (Lichtenberg 2004) although he investigated the fall in market valuation due to policy measures. It seems logical that if a fall in market valuation due to policy measures reduces future R&D expenditure, the same should apply to a drop in market valuation due to contagion shocks. We hope to carry out more tests as annual R&D expenditure for the year 2005 becomes available.

The regression results indicate that the changes in R&D expenditures are associated with higher R&D intensity and a higher liquidity. The coefficients have the predicted sign and are significant. We also controlled for size proxied by total equity of the firm to examine if larger firms with a greater R&D outlay and possibly more R&D projects have a greater flexibility to curtail their R&D spending. While the coefficient of the size factor is as expected, it is not statistically significant. It is instructive to note that firms with higher liquidity in fact scale back their R&D expenditure although they could have financed it. This lends further confirmation to our model that firms which carry out significant amount of R&D stay in close touch with other firms in the industry and match their R&D to the perceived future R&D efforts by the industry and the risk perception. These results are even more remarkable considering that the flexibility to reduce R&D expenditure would be lower in the immediate quarter following the contagion shock which took place on 30th September 2004.

7.4 Policy Implications

We observe that in hi-tech industries in general and for pharmaceutical industry in particular, market contagion shocks are frequent and result in a reduction future R&D. As such the market contagion shocks form an important aspect of R&D risks. Policy measures are needed to minimize such contagion. (Lichtenberg 2004), calls for stable policy regulations to promote pharmaceutical R&D in the context of reduction in R&D due to frequent policy changes. A more transparent process for FDA drug approvals and a more restrictive tort legislation would reduce the adverse impact of contagion shocks.(Bandow 1993) and (Patricia and Li-Wei 2000) have advocated a more liberal tort legal frame work to promote pharmaceutical R&D. Our findings on the feared high value law suits lend support to this view.

Another policy implication of our study is the need to encourage R&D alliances among pharmaceutical firms. Such alliances have been suggested by (Danzon, Nicholson et al. 2003)as the next step after alliances with biotech firms. The nature of contagion shocks and how the adverse impact on a major drug firm affects even its competitor would tend to support this view.

Section 8: **Conclusions**

We investigate the sudden and unpredictable contagion shocks in the R&D intensive industries; which to our knowledge has not been studied so far in the literature. Extant literature studies two types of risks associated with R&D, namely risks associated with success or failure of R&D projects on the one hand and policy changes by the government on the other. We note that both these types of risks evolve over time and participants including the firms, mangers and the investors can reasonably plan for them. Contagion shocks on the other hand are sudden and require a different approach from the study of other types of risks. We survey the trade and financial reports over the past ten years to assess the extent of such contagion shocks. We study the reports of all the seven industries which have been ranked as R&D intensive by (Chan, Lakonishok et al. 2001). We find that there are numerous and frequent market shocks which are labeled as contagion by the informed financial and industry analysts. These analysts also predict that there will be more such events in the future. We study the extant literature which studies the two other types of R&D risks and also the relevant finance literature which evaluates the link between R&D expenditure and stock market returns and the reverse relation between changes in stock market returns and subsequent changes in R&D.

We construct a model to describe the evolution of such contagion shocks in the R&D intensive industries and why they are so frequent. Our model has important predictions regarding the inevitability of such contagion shocks, their localized nature and how the role of the firm, the managers and the investors all tend to exacerbate the impact of these shocks. We also identify the characteristics of those firms in the industry which are likely to be more adversely affected. We derive a set of four testable hypotheses from our model in the context of the pharmaceutical industry. We choose the withdrawal of Vioxx by Merck as our contagion event. While it is appropriate and timely to study this event, our methodology is not industry specific. Indeed, we find a large number of possible contagion events from other R&D intensive industries which can be investigated by using our methodology.

Our testable hypotheses suggest that such contagion events will be highly localized to a subset of the industry and all the firms in this sub group will be adversely affected irrespective of possible short term competitive advantages. We also find that that more R&D intensive the firm the more adversely it is likely to be affected. Subsequently all the firms lower their R&D expenditure and again the maximum reduction happens in the more R&D intensive firms. We test our hypotheses on the sample of all listed pharmaceutical firms and find good empirical support for our model. Previous studies have examined the adverse effect on market valuation and subsequent R&D arising out of policy measures. We draw a parallel between these findings and our findings on market contagion.

The contagion shocks are frequent and reduce subsequent R&D in the industry. It is therefore appropriate to evolve policy measures that can minimize contagion shocks. Previous studies on the impact of policy issues in Pharmaceutical industry have called for a more liberal legal system and the fostering of industry alliances for joint R&D. We find that such measures will also mitigate the impact of contagion shocks.

There are obvious limitations to our study. The contagion event due to the withdrawal of Vioxx is still recent and the next full year data is not yet available. We hope to carry out fresh tests as additional data comes in. While there are contagion events in all R&D intensive industries and broadly they may have similar impacts, there are bound to be variations between industries and studying them can throw further light on this important phenomenon. All in all ours is the first study in this area and more such contagion events need to be investigated to better understand their impact on R&D.

Table -1 Summary of Possible Contagion Events in R&D Intensive Industries.

(Chan, Lakonishok et al. 2001) identify the most R&D intensive industries as Computer software (SIC 737), Pharmaceuticals (SIC 283), Computers and office equipment (SIC 357), Measuring Instruments (SIC 38), Electrical equipment (SIC 36), Communications (SIC 48) and Transportation equipment (SIC 37). We look for market driven events in these industries during 1996 / 2005, which based on financial and trade reports, had an industry wide negative impact. For our study, information was gathered on all financial, industry and popular press using Factiva and LexisNexis.

Industry	*SIC code*	*Possible Contagion events as per reports*	*Illustration*
Computer software	737	25	A series of accidents on Airbus in mid nineties blamed on tracking software in 1997/99:
Pharmaceuticals	283	30	A series of drug recalls and problems with diagnostic kits
Computers and office equipment	357	26	Sony's problems with copy protected music CDs,
Measuring Instruments	38	3	Accidents in chemical plants blamed on measuring instruments
Electrical equipment	36	4	Power outages, Edison law suit
Communications	48	5	Motorola misconnection issue. ATT outages.
Transportation equipment	37	5	Problems with SUVs, dumpers, special purpose cranes

Table -2 Summary of Possible Contagion Events in R&D Intensive Industries.

We look for market driven events in the pharmaceutical industry during 1996 / 2005, which based on financial and trade reports, had an industry wide negative impact. All of them pertained to product recall of approved drugs based on subsequent knowledge of serious adverse side effects. For our study, information was gathered on all financial, industry and popular press using Factiva and LexisNexis.

Brand	*Manufacturer*	*Date Banned*	*Side Effects*	*Prescribed For*
Avandia (rosiglitazone maleate)	Glaxo SmithKline	3-2000	heart failure, hepatitis, and liver failure	diabetes
Baycol (cerivastatin)	Bayer AG	8-2001	fatal rhabdomyolysis	cholesterol
Bextra (valdecoxib)	Pfizer	4-07-2005	heart attack, stroke, skin diseases	arthritis
Celebrex (celecoxib)	Pharmacia	stronger warnings		arthritis
Dexatrim (phenylpropanolamine) (PPA)	Bayer	11-2000	fatal strokes	cold, cough
Ephedra (ma huang)	Brayton Purcell	4-2004	high blood pressure, heart rate irregularity, brain hemorrhage, death	weight loss
Fen Phen (dexfenfluramine) (phentermine)	American Home Products (now Wyeth)	9-15-1997	heart valve damage, primary pulmonary hypertension	weight loss

Table -2 (cont'd)

Brand	*Manufacturer*	*Date Banned*	*Side Effects*	*Prescribed For*
Lotronex (alosetron)	Glaxo SmithKline	11-2000	ischemic colitis, abdominal pain,	irritable bowel
Paxil (paroxetine)	Glaxo SmithKline	stronger warnings	suicide	depression
Pondimin (fenfluramine)	American Home Products (now Wyeth)	9-15-1997	heart valve damage, primary pulmonary hypertension	weight loss
Propulsid (cisapride)	Janssen	3-2000	torsades de pointes, SIDS	heartburn
Redux (dexfenfluramine)	American Home Products (now Wyeth)	9-15-1997	heart valve damage, primary pulmonary hypertension	weight loss
Rezulin (troglitazone)	Warner-Lambert	3-2000	severe liver toxicity	diabetes 2
Vioxx (rofecoxib)	Merck	9-2004	heart attack, stroke	arthritis
Zyprexa (olanzapine)	Eli Lilly	stronger warnings	diabetes, hyperglycemia, ketoacidosis	mania, bipolar disorder

Table 3 Summary of Key Events – Withdrawal of Vioxx by Merck

The key events leading up to and after the withdrawal of the drug Vioxx by Merck are summarized below. For our study, information was gathered on all financial, industry and popular press using Factiva and LexisNexis.

Key Dates	*Events*
1999	United States Food and Drug Administration ("FDA") approved Vioxx (known generically as rofecoxib).
2000	The VIGOR study an independent investigation is published and indicates a significant 4-fold increased risk heart attack as compared to a competing drug. The finding was ambiguous and Merck interpreted it as the beneficial side effect of the competing drug rather than as an injurious side effect of Vioxx.
February 2001	The results of the VIGOR study were submitted to the United States Food and Drug Administration (FDA),
March 2001	Merck commenced the APPROVe (Adenomatous Polyp PRevention on Vioxx) study, a three year trial with the primary aim of evaluating other uses for Vioxx and also to study the cardiovascular safety aspects.
April 2002	FDA mandates warnings on Vioxx labeling concerning increased heart attack and stroke. This is based on VIGOR study contested by MERCK
September23, 2004	Eighteen months into the three year APPROVe study, Merck received results that supported previous findings of increased risk of heart attack among Vioxx users, two times more risk as against four times found earlier.
September 28 2004	, Merck notified the FDA that it was withdrawing Vioxx from the market.
September 30 2004	, Merck publicly announced the withdrawal

Table 3 (cont'd)

Key Dates	*Events*
November 5 2004	the medical journal *The Lancet* published the results of its analysis of the available studies. It concluded that "the unacceptable cardiovascular risks of Vioxx (rofecoxib) were evident as early as 2000..." *The Lancet* condemned Merck for having kept the drug on the market, despite its knowledge of the risks, and also criticized the FDA for its failure of regulatory oversight. Merck issues a rebuttal.
December 8, 2004	Merck held an investor's conference emphasizing the strong long term outlook for Merck.
August 19, 2005.	Merck was found liable in the death of a man who took Vioxx. A jury in Angleton, Texas awarded $253.4 million in damages. The fact that Merck apparently kept Vioxx on the market knowing its potential risks weighed heavily on the case. In addition, at the time of the verdict, there were over 4,000 other lawsuits pending against Merck regarding Vioxx.
November 3, 2005.	Merck won the second case in Atlantic City, New Jersey in a personal injury case, Humeston V. Merck.
November 29, 2005	The first federal trial in a multi-district litigation (MDL) on VIOXX began on in Houston, Texas.
December 12, 2005.	The trial ended in a hung jury and a mistrial was declared .According to the Wall Street Journal the jury hung by an eight to one majority, favoring the defense.

Table 4: Contagion Shocks in R&D Intensive Industry – Schematic Model

Schematic representation of the role of contagion shocks in R&D intensive industries. The R&D model is based on a harmonized reading Schumpeterian theory on business stealing and the imperfect competition theory.[20]

Stages	Firms / Industry Network and Monitoring	R&D Expenditure by industry	Investor
Stage 1 Single Firm	As there are no other firms, there is no monitoring of other firms by the managers.	Minimal. A single firm does not see the need to take up risky R&D	No costly monitoring of firms necessary
Stage 2 Many Firms	Firms fear business stealing by other firms .They keep tabs on other firms and fine tune their R&D expenditure with other firms in industry and industry R&D.	High levels of R&D. Firms carry out R&D for fear of "business stealing" by competitors.	Investors monitor R&D plans of firms as R&D expenditure is risky.
Stage 3	Costly mistake by one firm in the race for innovation. Market Shock arises		
Stage 4 Firm takes corrective action and plans for a reduction in R&D expenditure.	All other firms consider R&D plans to be more risky in the light of the shock. They continue to monitor other firms and reduce their R&D expenditure plans in line with the other firms in the industry. A localized contagion develops.	Industry R&D declines as firms regard R&D as more risky and reduce their R&D in line with one another.	Investors bring down firm values based on perceived higher R&D risks and expected lower R&D expenditure and slower launch of new products
Stage 5	Reduced firm values result in further lowering of R&D by the managers		

[20] Schumpeter (2002), Dixit (1988)

Table 5 Profile and Summary Information of Firms Used in the Study.

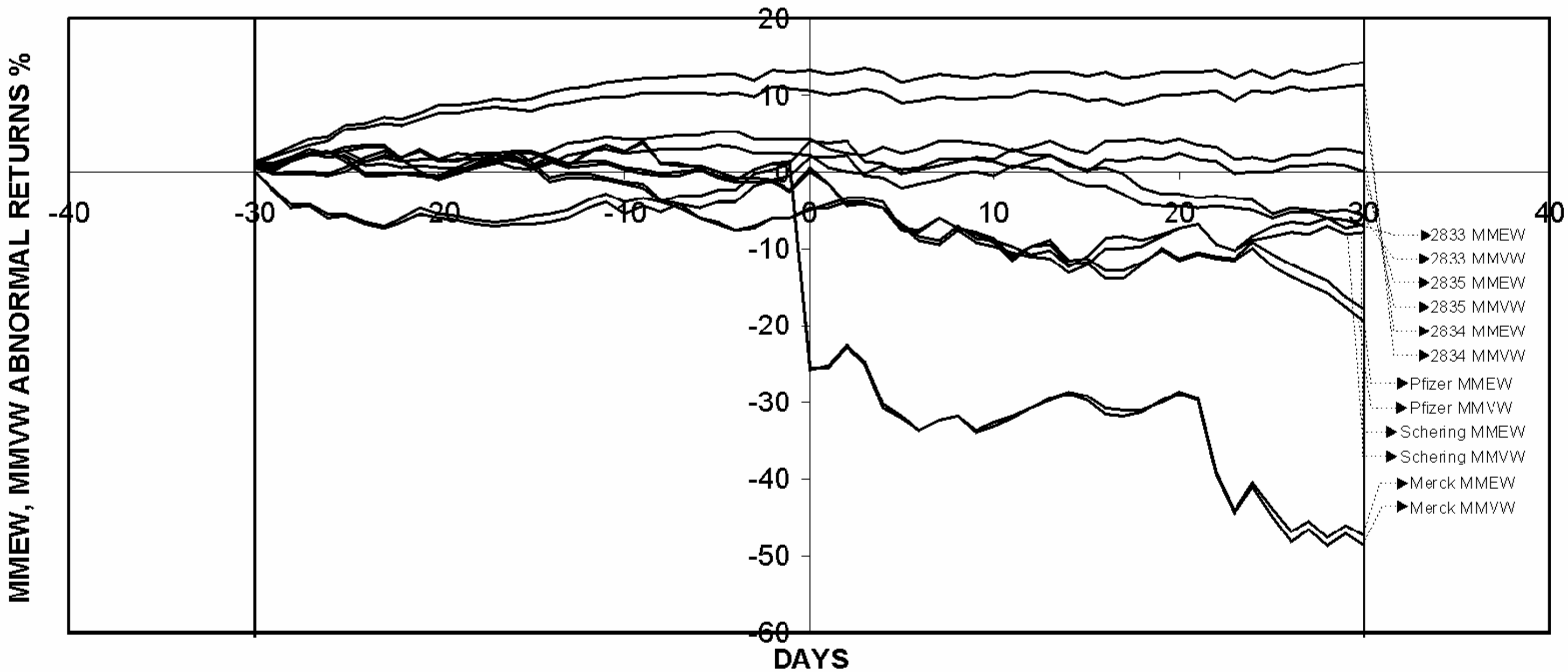
We investigate all pharmaceutical firms which were active at this time. This includes all listed pharmaceutical firms at that time in the SIC codes 2833 Medicinal Chemicals and Botanical Products, 2834 Pharmaceutical Preparations, 2835 In-Vitro and In-Vivo Diagnostic Substances (except in-vitro diagnostic) and in-Vitro and In-Vivo Diagnostic Substances (in-vitro diagnostic substances). We employ the financial and accounting data of these firms for the year 2004 and quarterly R&D data for the first half of 2004 and 2005 to analyze the abnormal returns of stock prices and relate it to the firm characteristics. There are six firms under SIC sub code 2833, 105 firms under SIC sub code 2834 of interest to us and 12 firms under SIC sub code 2835. R&D intensity refers to intensity with respect to total assets; Liquidity is calculated as the percentage liquid assets to the total assets.

(US $ million)

Variable	*Mean*	*Std. Dev.*	*Min*	*Max*
Sales	3209	9366	0	52516
R&D Expenditure	546	1608	0	10093
Total Assets	5970	18856	4	123684
Total Equity	2960	9703	-36	68085
R&D Intensity	27	25	0	177
Tobin's Q	11709	35028	12	201771
Liquidity	56.32	31.17	2.28	100.00

Table 6 Cumulative abnormal Returns of Pharma Sectors and Firms Between 31 Aug 31,2004 and October 30,2004(Sixty Day Window)

Cumulative abnormal returns are calculated for the SIC sub codes 2833, 2834 and 2835 and the firms of interst Merck, Pfizer and Schering under four models namely Market model equally weighted index, Market model value weighted index, Market adjusted model equally weighted index and Market adjusted model value weighted index. The returns under the first two models are shown here,



SIC CODES	Abnormal Returns based on
2833 2834 2835	**MMEW** - Market model equally weighted index **MMVW** - Market model value weighted index

Table 7 Analysis of Cumulative abnormal Returns of Pharma SIC code 2833 around September 30,2004(Sixty Day Window)

Cumulative abnormal returns are calculated for the SIC sub codes 2833, under four models namely Market model equally weighted index, Market model value weighted index, Market adjusted model equally weighted index and Market adjusted model value weighted index. The returns for select windows are shown here.

Widows Days	Positive/ Negative	MMEW				MMVW			
		Cumulative	Precision			Cumulative	Precision		
		Abnormal	Weighted		Generalized	Abnormal	Weighted		Generalized
		Return	CAAR	Z	Sign Z	Return	CAAR	Z	Sign Z
(-1,+1)	3:03	3.08%	1.65%	1.131	0.157	3.35%	1.66%	1.162	0.148
(-1,+5)	2:04	-0.91%	-1.65%	-0.739	-0.661	-0.54%	-1.49%	-0.674	-0.67
(-1,+10)	3:03	0.69%	-0.17%	-0.056	0.157	1.20%	0.27%	0.096	0.148
(-3,+1)	4:02	5.97%	3.46%	1.839*	0.975	5.96%	3.25%	1.754*	0.148
(-3,+5)	3:03	1.97%	0.17%	0.066	0.157	2.08%	0.10%	0.042	0.148
(-3,+10)	3:03	3.58%	1.65%	0.523	0.157	3.82%	1.85%	0.599	0.148
Widows Days	**Positive/ Negative**	**MAEW**				**MAVW**			
		Cumulative	**Precision**			**Cumulative**	**Precision**		
		Abnormal	**Weighted**		**Generalized**	**Abnormal**	**Weighted**		**Generalized**
		Return	**CAAR**	**Z**	**Sign Z**	**Return**	**CAAR**	**Z**	**Sign Z**
(-1,+1)	3:03	3.30%	1.70%	0.932	0.17	3.63%	1.99%	1.097	0.103
(-1,+5)	3:03	-0.70%	-2.41%	-0.866	0.17	-0.06%	-1.78%	-0.642	0.103
(-1,+10)	2:04	0.67%	-0.38%	-0.105	-0.648	1.76%	0.86%	0.237	-0.715
(-3,+1)	4:02	6.15%	3.94%	1.675*	0.989	6.34%	4.06%	1.732*	0.92
(-3,+5)	2:04	2.14%	-0.17%	-0.053	-0.648	2.65%	0.29%	0.092	0.103
(-3,+10)	3:03	3.52%	1.86%	0.472	0.17	4.47%	2.93%	0.747	0.103

Table 7 Analysis of Cumulative abnormal Returns of Pharma SIC code 2835 around September 30, 2004(Sixty Day Window)

Cumulative abnormal returns are calculated for the SIC sub codes 2835, under four models namely Market model equally weighted index, Market model value weighted index, Market adjusted model equally weighted index and Market adjusted model value weighted index. The returns for select windows are shown here.

Windows/ Days	Positive/ Negative	MMEW				MMVW			
		Cumulative Abnormal Return	Precision Weighted CAAR	Z	Generalized Sign Z	Cumulative Abnormal Return	Precision Weighted CAAR	Z	Generalized Sign Z
(-1,+1)	2:10	-1.85%	-1.52%	-1.123	-2.058*	-1.35%	-1.09%	-0.798	-2.038*
(-1,+5)	3:09	-2.25%	-1.86%	-0.9	-1.479$	-1.66%	-1.33%	-0.635	-0.88
(-1,+10)	7:05	-1.21%	-1.27%	-0.468	0.837	-0.82%	-0.81%	-0.296	0.858
(-3,+1)	3:09	-2.67%	-2.71%	-1.552$	-1.479$	-2.41%	-2.53%	-1.439$	-1.459$
(-3,+5)	4:08	-3.07%	-3.05%	-1.302$	-0.9	-2.72%	-2.77%	-1.172	-0.88
(-3,+10)	4:08	-2.02%	-2.46%	-0.841	-0.9	-1.88%	-2.25%	-0.764	-0.88
Windows/ Days	Positive/ Negative	MMEW				MMVW			
		Cumulative Abnormal Return	Precision Weighted CAAR	Z	Generalized Sign Z	Cumulative Abnormal Return	Precision Weighted CAAR	Z	Generalized Sign Z
(-1,+1)	2:1<	-1.90%	-1.65%	-1.031	-1.624$	-1.57%	-1.26%	-0.782	-1.624$
(-1,+5)	3:9(	-2.26%	-2.00%	-0.822	-1.047	-1.62%	-1.25%	-0.508	-1.047
(-1,+10)	7:05	-1.08%	-1.39%	-0.434	0.686	0.01%	-0.09%	-0.028	0.686
(-3,+1)	2:1<	-2.68%	-3.05%	-1.479$	-1.624$	-2.49%	-2.82%	-1.358$	-1.624$
(-3,+5)	3:9(	-3.04%	-3.41%	-1.232	-1.624$	-2.54%	-2.81%	-1.009	-1.624$
(-3,+10)	5:07	-1.87%	-2.79%	-0.809	-0.469	-0.92%	-1.65%	-0.475	-0.469

Table 8 Analysis of Cumulative abnormal Returns of Pharma SIC code 2833 around September 30, 2004(Sixty Day Window)

Cumulative abnormal returns are calculated for the SIC sub codes 2833, under four models namely Market model equally weighted index, Market model value weighted index, Market adjusted model equally weighted index and Market adjusted model value weighted index. The returns for select windows are shown here.

Windows/ Days	Positive/ Negative	MMEW				MMVW			
		Cumulative Abnormal Return	Precision Weighted CAAR	Z	Generalized Sign Z	Cumulative Abnormal Return	Precision Weighted CAAR	Z	Generalized Sign Z
(-1,+1)	35:67	-0.96%	-0.46%	-0.947	-2.590**	-0.54%	-0.14%	-0.294	-1.715*
(-1,+2)	35:67	-0.74%	-0.42%	-0.758	-1.599$	-0.17%	0.03%	0.059	-1.12
(-1,+3)	39:63	-0.34%	-0.14%	-0.221	-0.409	0.23%	0.40%	0.653	0.069
(-1,+5)	31:71	-2.12%	-2.47%	-3.357**	-2.194*	-1.51%	-1.85%	-2.532**	-1.517$
(-1,+7)	34:68	-1.25%	-1.76%	-2.103*	-1.797*	-0.58%	-1.02%	-1.212	-1.715*
(-1,+9)	32:70	-1.64%	-1.78%	-1.929*	-2.194*	-1.04%	-1.04%	-1.122	-1.517$
(-1,+10)	36:66	-1.22%	-1.62%	-1.685*	-1.599$	-0.52%	-0.75%	-0.772	-1.319$
(-1,+15)	33:69	-1.86%	-2.05%	-1.782*	-2.590**	-0.81%	-0.70%	-0.6	-1.319$
(-1,+20)	41:61	-0.90%	-0.84%	-0.646	0.187	-0.38%	0.01%	0.009	0.267
(-3,+1)	36:66	-0.24%	0.08%	0.134	-1.004	-0.03%	-0.03%	0.363	-0.922
(-3,+2)	40:62	-0.02%	0.12%	0.173	0.583	0.34%	0.34%	0.588	1.06
(-3,+3)	36:66	0.38%	0.40%	0.547	-0.607	0.75%	0.75%	1.051	-0.129
(-3,+5)	32:70	-1.39%	-1.93%	-2.314*	-1.797*	-0.99%	-0.99%	-1.792*	-1.715*
(-3,+7)	35:67	-0.53%	-1.22%	-1.318$	-1.202	-0.06%	-0.06%	-0.698	-0.922
(-3,+9)	33:69	-0.91%	-1.24%	-1.236	-1.400$	-0.53%	-0.53%	-0.665	-1.12
(-3,+10)	37:65	-0.50%	-1.09%	-1.042	-1.202	0.00%	0.00%	-0.361	-0.922
(-5,+1)	36:66	-0.20%	0.06%	0.089	-1.004	0.20%	0.20%	0.565	-0.526
(-10,+1)	36:66	0.22%	0.24%	0.255	0.187	1.02%	1.02%	1.193	0.664

(Table 9 Cont'd)

Windows/ Days	Positive/ Negative	MAEW				MAVW			
		Cumulative Abnormal Return	Precision Weighted CAAR	Z	Generalized Sign Z	Cumulative Abnormal Return	Precision Weighted CAAR	Z	Generalized Sign Z
(-1,+1)	35:67	-1.30%	-1.37%	-2.261*	-2.139*	-0.97%	-0.98%	-1.609$	-1.526$
(-1,+2)	35:67	-1.19%	-1.49%	-2.131*	-2.139*	-0.72%	-0.94%	-1.336$	-0.93
(-1,+3)	39:63	-0.93%	-1.33%	-1.701*	-1.343$	-0.42%	-0.72%	-0.91	-0.93
(-1,+4)	37:65	-1.51%	-2.60%	-3.025**	-1.741*	-1.09%	-2.11%	-2.457**	-1.327$
(-1,+5)	31:71	-2.98%	-4.48%	-4.829**	-2.936**	-2.34%	-3.75%	-4.031**	-2.519**
(-1,+6)	33:69	-2.75%	-4.29%	-4.329***	-2.538**	-2.00%	-3.44%	-3.460***	-2.519**
(-1,+7)	34:68	-2.40%	-3.90%	-3.714***	-2.339**	-1.59%	-2.96%	-2.807**	-1.923*
(-1,+8)	29:73	-2.80%	-4.12%	-3.716***	-3.334***	-2.01%	-3.18%	-2.860**	-2.519**
(-1,+9)	32:70	-3.08%	-4.27%	-3.672***	-2.737**	-2.20%	-3.21%	-2.757**	-2.122*
(-1,+10)	36:66	-2.82%	-4.12%	-3.391***	-1.940*	-1.73%	-2.82%	-2.315*	-1.327$
(-1,+15)	33:69	-4.10%	-5.60%	-3.874**	-2.538**	-2.57%	-3.77%	-2.598**	-0.731
(-1,+20)	41:61	-3.79%	-4.99%	-3.038**	-0.945	-2.75%	-3.76%	-2.279*	-0.135
(-3,+1)	36:66	-0.85%	-1.01%	-1.292$	-1.940*	-0.66%	-0.80%	-1.021	-1.923*
(-3,+2)	40:62	-0.74%	-1.13%	-1.321$	-1.144	-0.41%	-0.76%	-0.885	-0.731
(-3,+3)	36:66	-0.48%	-0.97%	-1.05	-1.940*	-0.10%	-0.54%	-0.578	-1.724*
(-3,+4)	36:66	-1.06%	-2.24%	-2.257*	-1.940*	-0.78%	-1.94%	-1.949*	-1.526$
(-3,+5)	32:70	-2.53%	-4.12%	-3.917**	-2.737**	-2.03%	-3.57%	-3.387**	-2.519**
(-3,+6)	34:68	-2.30%	-3.93%	-3.548**	-2.339**	-1.69%	-3.26%	-2.935**	-2.122*
(-3,+7)	35:67	-1.95%	-3.54%	-3.050**	-2.139*	-1.27%	-2.78%	-2.387**	-2.122*
(-3,+8)	33:69	-2.35%	-3.76%	-3.096**	-2.538**	-1.69%	-3.00%	-2.465**	-2.321*
(-3,+9)	33:69	-2.64%	-3.91%	-3.093**	-2.538**	-1.89%	-3.04%	-2.396**	-1.923*
(-3,+10)	37:65	-2.37%	-3.76%	-2.865**	-1.741*	-1.42%	-2.64%	-2.009*	-1.327$
(-5,+1)	36:66	-1.08%	-1.38%	-1.485$	-1.940*	-0.63%	-0.85%	-0.911	-1.724*
(-10,+1)	39:63	-1.33%	-1.92%	-1.584$	-1.343$	-0.29%	-0.70%	-0.576	-0.333

Table 10 Regression Analysis of Cumulative abnormal Returns of Pharma SIC code 2834 against Firm Characteristics.

Cumulative abnormal returns are calculated for the SIC sub codes 2833, under four models namely Market model equally weighted index, Market model value weighted index, Market adjusted model equally weighted index and Market adjusted model value weighted index. The returns are regressed against firm characteristics. Regression results for select windows are shown here. R&D intensity refers to intensity with respect to total assets; Liquidity is calculated as the percentage liquid assets to the total assets.

Variable	*MMEW Returns*			*MMVW Returns*		
	C-1,+1	C-1,+5	C-1,+10	C-1,+1	C-1,+5	C-1,+10
TOTEQUITY	0.090	0.005	0.004	0.020	0.010	0.006
	(0.08)	(0.26)	(0.07)	(0.11)	(0.29)	(0.37)
R&DIntensity	-0.242	-0.369	-0.423	-0.244	-0.371	-0.154
	(1.90)	(2.16)*	(2.10)	(1.72)	(2.19)*	(1.97)
TQ	-0.005	-0.010	-0.009	-0.000	-0.000	-0.000
	(0.05)	(0.29)	(0.19)	(0.20)	(0.44)	(0.64)
Liquidity	-0.103	-0.109	-0.104	-0.097	-0.103	-0.088
	(2.11)*	(1.97)	(2.06)	(2.19)	(1.99)	(1.96)
Constant	4.142	2.259	2.520	4.200	2.459	1.322
	(2.25)*	(1.02)	(0.81)	(2.29)*	(1.12)	(0.38)
Adj. R^2	0.26	0.26	0.18	0.25	0.28	0.18

t statistics in parenthesis

Variable	MMEW Returns			MMVW Returns		
	C-1,+1	C-1,+5	C-1,+10	C-1,+1	C-1,+5	C-1,+10
TOTEQUITY	0.070	0.004	-0.002	0.010	0.012	-0.004
	(0.20)	(0.28)	(0.17)	(0.20)	(0.28)	(0.17)
R&DIntensity	-0.275	-0.424	-0.492	-0.275	-0.424	-0.492
	(1.94)	(2.76)*	(2.27)*	(1.94)	(2.76)*	(2.27)*
TQ	-0.010	-0.012	0.010	-0.000	-0.000	0.000
	(0.43)	(0.48)	(0.22)	(0.43)	(0.48)	(0.22)
Liquidity	-0.075	-0.054	-0.024	-0.075	-0.054	-0.024
	(1.54)	(1.98)	(1.83)	(1.94)	(1.83)	(1.33)
Constant	3.428	0.627	-0.234	3.758	1.267	0.850
	(1.87)	(0.32)	(0.08)	(2.05)	(0.64)	(0.30)
Adj. R^2	0.24	0.31	0.19	0.24	0.31	0.29

t statistics in parenthesis

Table 11 Regression Analysis of Change in Quarterly R&D against Firm Characteristics.

Changes in percentage quarterly R&D expenditure from first quarter 2005 over first quarter 2004 are regressed against firm characteristics for all pharmaceutical firms under SIC code 2834 barring MERCK. We collect the data for seventy eight out of the one hundred and five firms in the sub code and regression analysis is carried out on this sample. R&D intensity refers to intensity with respect to total assets; Liquidity is calculated as the percentage liquid assets to the total assets.

Variable	Percentage Change In First Quarter R&D
TOTEQUITY	-0.001
	-0.3
R&DIntensity	-22.54
	-1.98
TQ	-0.02
	-0.2
Liquidity	4.538
	-2.12
Constant	177.554
	-1.18
R-squared	0.35

t statistics in parenthesis

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