AGRICULTURAL RESEARCH AND DEVELOPMENT IN INDIA AND THE COST OF CAPITAL INVESTMENT

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A thesis submitted to the

Graduate School-New Brunswick

Rutgers, The State University of New Jersey

In partial fulfillment of the requirements

For the degree of

Master of Science

Graduate Program in Food and Business Economics

Written under the direction of

Dr. Carl Pray

And approved by

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New Brunswick, New Jersey

JANUARY 2014

ABSTRACT OF THE THESIS

Agricultural Research and Development in India and the Cost of Capital Investment

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The cost of research and development is a topic rarely explored for developing nations. The ability for a developing nation's firms to acquire capital to invest in R&D is reflected by the government's policies toward innovation, conditions affecting the acquisition of funds within the firm, conditions affecting the acquisition of funds outside the firm, and the availability of venture-capital financing and capital gains taxation. This thesis provides a compilation of some of the vast amount of economic literature on R&D, a unique framework surrounding the effect of cost on R&D, and an empirical test of the importance of the availability of capital as a determinant of R&D. The cost variables used include firm data on the annual borrowings, leverage, subsidies and grants, and interest rates. In addition, annual sales data, the age of the firm, and the Herfindahl-Hirschman Index (HHI) were used to include revenue-related aspects a firm faces that might affect R&D expenditure. Using an unbalanced Indian firm-level panel, the goal of this thesis is to analyze of the relationship between the cost of capital investment and R&D while also including revenue-related variables for the pesticide and fertilizer industries. The dataset used for this analysis comes from The Centre for Monitoring Indian Economy (CMIE) which includes 1989-90 until 2009-2010. In addition, it was supplemented with variables from IMF and survey data collected by Pray and Nagarajan (2013). The empirical analysis utilizes a Random Effects General Least Squares regression for two models with two variations with different dependent variables: R&D expenditure and R&D intensity. The results show that a firm's level of debt and external financing are positively related to R&D to start, supporting the notion that a firm's ability to acquire capital will affect its total R&D expenditure. However, debt is negatively related to R&D after a certain threshold is passed, supporting the concept of risk aversion among firms. In addition, the results supports previous literature which found that variables such as sales affect R&D positively. Finally, the results show that additional research is necessary to understand more fully the nature of cost in R&D investment.

Acknowledgements

I would, first and foremost, like to extend my most sincere gratitude and respect to my primary advisors Dr. Carl Pray and Dr. Latha Nagarajan. Dr. Pray provided overall guidance, structure, and encouragement to succeed. Dr. Nagarajan was instrumental in guiding my empirical results and econometrics. They were both readily available and took precious time out of their schedule to help me. Thanks to Dr. Jin for being a valuable contributor in my committee. She offered great suggestions for the empirical analysis and how to improve it. Also thanks to Dr. Gal Hochman for his great ideas during my thesis defense. I couldn't forget Dr. Sanjib Bhuyan, the program director for the Food and Business Economics master's program, for overall guidance and awareness of department policies. Finally, thank you to the entire department for helping me whenever needed.

Special thanks to my family. For without their love and support, I would have surely lost myself.

Table of contents

List of tables

List of illustrations

Chapter 1: Introduction

In the wake of growing populations, scarce resources, and uncertain estimates of arable land, there is now an unprecedented pressure on technology to produce better production methods in agriculture. According to the IIASA (International Institute for Applied Systems Analysis), the world's population is expected to increase by 50% between 2000 and 2050. It is essential to ensure to deliver a 70% increase in food production by intensifying agriculture through yield increases and multiple uses of the land (IIASA, 2009). However, as environmental constraints and scarcity become ever more rigid, sustainability is crucial. It is essential that new, clean, and efficient technologies are developed and spread as global development and population growth reaches heights never seen in history. To induce this necessary technological change however, we must first ask what is the mechanism behind the development of new inventions and technological growth?

The protagonist in the mythology of invention is a lone creative genius toiling away in his basement, scorned by his neighbors for his crackpot ideas and wasted money towards his research. Although there are exceptions, the general rule in the modern age is that this mythology is simply false. Inventions today are by and large created by organized teams using collaborative research. Additionally, these teams and their research are motivated by different incentives within their respective sector. Publicly funded research is motivated to provide sound information and knowledge to better support policy decisions to more effectively allocate resources. Privately funded research is motivated largely by the prospect of finding new revenue streams and additional profit.

The United States R&D landscape in the year 2000 was largely dominated by the private sector. 68% of all R&D funding that year was funded by the private sector and 29% by the public sector including research centers and other governments. On top of that, 75% of R&D performance was done by the private sector while 11% was done by the public sector. Although the government pays more for research than is actually performed, their importance in the research arena cannot be understated: most of the research accomplished in the public sector is the basic research which more advanced private research is built upon. Although only 14% of all R&D is performed by universities, with only 2% of R&D funding, they perform about 50% of basic research. The realization that there is a relationship between public and private research sets the foundation for a vast array of developmental economics literature, especially regarding agricultural innovation. (Scotchmer 2004, p. 16-23)

Agricultural R&D, globally, has seen growth in its public funding within recent history. Over the last two decades of the 20th century, worldwide public investments in agricultural research increased by 51 percent in inflation-adjusted terms, from an estimated $15.2 billion (in 2000 international dollars) in 1981 to around $23 billion in 2000. In 2008, total global public spending on agricultural R&D was $31.7 billion (2005 PPP dollars). Technological progress and improvements in agricultural productivity can counteract the stresses that population growth and environmental constraints may place on the world in the future. Increasing agricultural productivity can have a positive impact on economic growth, poverty reduction, and food security (Parikh 2013).

The relationship between public and private R&D expenditure is very different in developing and developed nations. Consistent with the R&D shares found in the United

States, among developed countries, privately funded research accounted for more than half of total agricultural research. However, in developing countries, privately funded research accounted for a mere 6.3%. (Pardey 2006)

Table 1. Public & private agricultural R&D investments in the world and India

	Expenditure (2000 million U.S. dollars, PPP adjusted)[a]		**Share of total expenditure**	
	Public	Private	Public	Private
Developing Countries (2000)	12,819	862	93.7	6.3
Developed Countries (2000)	10,191	12,086	45.7	54.3
India (2008/09)[b]	497.36-607.84	221.92	61.2-64.73	23.58-27.29

Sources:
1)'Developing Countries' and 'Developed Countries' data are from Pardey et al. (2006) 2) Indian Private R&D data from Pray and Nagarajan (2011) 3) Indian Public R&D data based on Beintema et al. (2008).
Notes:
[a] Figures are expressed as real expenditures, calculated by deflating nominal expenditures in local currency using a 2000 price deflator, and converting to U.S. dollars using purchasing power parity (PPP) exchange rates for 2000.
[b] The public-sector investment figures for 2008/09 are projected from ASTI's (2011)) last survey estimates of Indian public research in millions of 2000 US dollars. ASTI calculated 6.4 percent growth in public-sector investment between 1981 and 2003, and 2.9 percent growth between 2000 and 2003. To calculate the first numbers in column 3, we used the 2000–2003 period growth rates of 2.9 percent for public agricultural investment and projected for 2008/09 to compute the share of public-sector R&D investment in total R&D investment. To calculate the second numbers in column 3 we used the 1981–2003 period growth rate of 6.4 percent for public agricultural investment and projected for 2008/09 to compute the share of the public sector in total investment. (Pray and Nagarajan 2012)

Although there is some literature on agricultural R&D and its determinants, the utilization of financial variables to understand how they affect a firm's decision to invest in R&D is understated and relatively unexplored. For this thesis, I explore this relationship during a period of the emergence of India as a liberalized economy. As shown in the literature, the ability for a developing nation's firms to acquire capital to invest in R&D is reflected by the government's policies toward innovation, conditions affecting the acquisition of funds within the firm, conditions affecting the acquisition of funds outside the firm, and the availability of venture-capital financing and capital gains taxation.

As this thesis explores how variables that affect the cost of R&D has played into India's R&D expenditure, it's important to note that doing such an analysis for a recently liberalized developing country is somewhat new ground in economic research. Nonetheless, these cost variables most certainly has played a role in the way liberalization has affected innovation in India. The goal of this thesis is to provide support to the notion that the development and liberalization of Indian financial markets has allowed for much easier ways of gathering financing outside of internal funds, and effectively reducing the cost of R&D over time.

Chapter 2: Background

Indian Research Environment

With the future plight of food security and economic stability in mind, India, the second most populated country on the planet, becomes a country of great interest to developmental economists. As discussed above, agricultural R&D funding is one of the major factors that increases agricultural productivity. In recognition of the impact of research, the Indian government's funding for research more than doubled between 1996 and 2009 (Pal, Rahija, Beintema 2012). Unlike OECD countries, private sector agricultural research has played only a small role in funding Indian agricultural research - 17% of total agricultural research in the mid 1990s according to Pray and Basant (2001).

Within the past century, the Indian research system has shown many successes, most notably with the Green Revolution in the 1960's, 70's, and 80's. There have been several major changes in the Indian agricultural input industry throughout recent history. Private sector sales have seen explosive increases in various industries including seeds, pesticides, machinery, animal genetics and medicine, and animal feed. Within the government owned input industry, however, sales have seen sharp declines for agricultural inputs. Additionally, the private sector has seen growth in its presence within the global market as many firms now compete with multinationals from the United States, Europe, and China.

As noted before, the Indian government has also increased its funding to agricultural research since the late 1990s, but, to date, the country has invested a lower percentage of its agricultural output in research than either Brazil or China, both in absolute terms and as a share of its agricultural GDP. Policy and institutional reforms affecting agriculture have also been less pronounced in India than in the other two countries (Fuglie and Schimmelpfennig 2010).

There are many different institutions in India that receive funding for agricultural research. The Indian Council of Agricultural Research is funded mostly by the central government and in small part by foreign donations. Public funding and performance dwarf the private sector's counterparts. One goal of economists studying agricultural research is to provide information regarding what influences private R&D investments. The purpose of this paper is to understand a piece of that puzzle by incorporating several cost aspects to understand their effect on research funding and performance on private research in India. (Evenson, Pray, Rosegrant 1999)

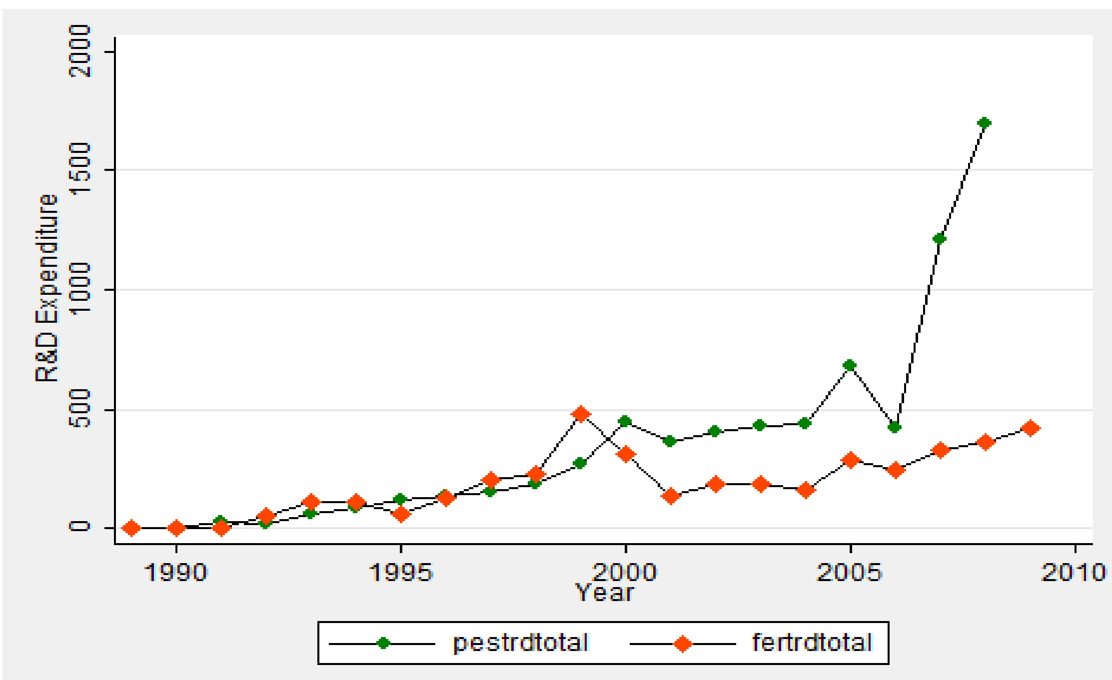
Studies have empirically shown the impressive performance of the system, with annual rates of return to investment in research ranging from 35 to 155 percent. (Evenson, Pray, and Rosegrant 1999). It is no surprise that recent studies (Pray and Nagarajan 2012) provide data that research expenditure by private firms has gone from US $24 million in the 1980s to $250 million in 2009 (2005 US dollars). Now, nearly a third of total agricultural R&D expenditure in India is spent by the private sector.

Agricultural biotechnology has seen great progress in the past few decades. In India specifically, Qaim and Zilberman (2003) found, using 157 farms across three states, that average yields of Bt (Bacillus thuringiensis) cotton, genetically modified with the natural insecticide, exceeded those of non-Bt counterparts by 80%. Insecticide amounts on Bt plots were reduced by almost 70%, both in terms of commercial products and active ingredients. Most of these reductions occurred in highly hazardous chemicals, such as organophosphates, carbamates, and synthetic pyrethroids, belonging to international toxicity classes I and II. The literature points towards a huge opportunity for innovation in agricultural biotechnology. However, in the past, within the pesticide and fertilizer industries, there have been economic policies which have hindered R&D growth and have represented a cost to capital acquisition.

Indian Pesticide and Fertilizer Industry

The importance of understanding the context and history of the fertilizer and pesticide industries can be seen in the immense industrial policy changes implemented over the past few decades. Economic liberalization has allowed for several improvements to these two industries however more in pesticide than in fertilizer. (Pray and Nagarajan 2012)

Figure 1. Indian R&D spending, fertilizer & pesticide industries, 1989-2009



Note: Total R&D expenditure for all firms per year in dataset used in this analysis. Source: Survey data from Pray and Nagarajan (2013)

By and large, the key driver in policy changes and R&D growth has been increased demand for agricultural inputs due to higher incomes and population growth. However, R&D growth observed much more in the pesticide industry than fertilizer as seen by each industry's research intensity, a firm's R&D expenditure divided sales (%). Both industries have experienced sales growth, however only pesticide's research intensity has increased over time. The reason for this difference, according to Pray and Nagarajan (2012), is due to government intervention and regulation in the form of quotas and price controls in the fertilizer industry. Consequently, fertilizer firms have little reason to be innovative. In 2005, the government allowed 100% FDI into the industry. However, the regulations still exist today. As discussed below, this supports David, Hall, and Toole's (2000) notion that government treatment of R&D can represent a cost to capital.

In the pesticide industry, there were big changes to the industry from economic liberalization. In the 1980's, pesticides with new active ingredients (AIs) were allowed to be imported for a limited time at 150% tariff and then must be manufactured in India once the temporary timeframe expired. In addition, 50% of the formulation of pesticides was reserved for small businesses in India and no imports were allowed. In the 1990's, the tariff was reduced to 35%, but imports of formulated products was still not allowed. However, they removed the reservation for small scale operations. Currently, we can see vast changes since the start of liberalization: Imports of formulated products have been allowed since 2004. In 2005, the country joined the WTO's Trade-Related Aspects of Intellectual Property Rights (TRIPS). (Pray and Nagarajan 2012)

Modern advances in financial markets and policy has been highly influential to agribusiness as a whole and R&D expenditure, affecting both the pesticide and fertilizer industries. The cost of capital investment in R&D is in part seen by the support of (or lack thereof) financial institutions to lend and invest in agribusiness. The development of stock markets in India and the interest of Indian and foreign investors in investing in Indian agribusiness has created opportunities for companies to raise money for all types of expenditures including R&D. (Pray and Nagarajan 2012)

Chapter 3:

Literature Review

As an introduction to innovation studies as a whole, the induced innovation model, first formulated by J.R. Hicks, can add structure to an analysis of the influences of R&D in the agricultural sector. Technological change in agriculture can be attributed to land or labor scarcity and relative factor prices that reflect this scarcity. When the cost of investing in technology is cheaper than simply hiring more labor or land, it creates an environment where technological R&D is encouraged.

The induced innovation hypothesis was researched further by Hayami and Ruttan (1970) as a way to interpret technological progress as endogenous to the economic system. They hypothesized that a combination of two factors will incentivize private and public R&D efforts: 1) the effect of resource endowments on the availability of factors of agricultural production and 2) input and product prices. Although these two ideas are related, the main difference is the unique institutions that countries have developed in response to their resource endowments.

More specifically, institutional changes within intellectual property rights arena can provide more of an incentive for corporations to invest in new technologies. The ability to acquire patents ensures companies that their invested time and resources will be profitable and less risky. Market exclusivity of their newly created product is viewed as an incentive for R&D. Especially within agricultural biotechnology, where seeds can easily be copied and monitoring can be difficult, a safe investment atmosphere is essential. Of course, it is worth mentioning that patents may not always contribute positively to innovation as many inventions may not be commercialized immediately and, in the extreme case, never at all. However, for this analysis, we are not focusing on the flaws of the patent system but rather its effect on innovation within the agricultural sector of India.

Using the induced innovation model as a framework for analysis, Pray and Fuglie (2000) outlined three sets of factors which influence agricultural R&D efforts. The first set consists of economic determinants. The market size of products and the demand for new technology has been shown to be of the largest determinants for R&D investments. Furthermore, research is also influenced by the supply and relative cost of agricultural inputs and resources. The second set of factors pertains to technological opportunity for developing new technology. Successful innovations can be constrained by the prevailing level of basic scientific knowledge and the cost of research inputs (one of which is financial capital). The third one is appropriability or the ability of researchers to acquire the economic benefits from research, it determines and influences the industry concentration and research (Schimmelpfennig, Pray and Brennan 2004).This involves the ability of firms to capture the economic benefits of an innovation. Firms need some guarantee to make sure that they will recoup their investments in research and new product development and earn profits. As a result, they will not undertake investments in developing new technology which can be easily reproduced by other rival firms.

Pray, Fuglie, and Johnson (2007) conducted an analysis concerning the effect of policies and regulations on private agricultural research in developing nations. The study concluded that there were four factors which induced innovation within the private sector: 1) The existence of a sizeable market for agricultural inputs will positively affect innovative research. 2) As noted above, a firm must have the certainty and atmosphere where it would be profitable to invest. In other words, they must be able to capture the benefits of their own research. 3) As a result of the human-capital-intensive nature of agricultural research, a strong public research system is crucial for the benefits of basic research to transfer to the private sector. 4) Understanding consumer preferences for safe foods and environmentally friendly agricultural practices will sustain demand for new goods. If there's a strong market for agricultural goods, there is an incentive for private research and innovation.

Exclusivity has been proven crucial to create the pro-investment atmosphere that tends to loosen firms pockets. As stated above, this could be achieved artificially via intellectual property rights (IPR) legislation. There is a high correlation of the intellectual property protection, an index concerning worldwide protection, in a country and the R&D is very strong (Varsakelis 2000). Protection is considered as an institutional factor influencing innovation activity by systems approach to innovation (Edquist 1997). It has been established by OECD (1997) and some researchers (Yang and Maskus 1999) that patents serve as a major incentive for R&D, they affect positively the R&D activity. According to a survey of US firms conducted in 1991 (Mansfield 2000), IPR protection was a very important factor in firm decisions to invest, transfer technology and conduct research in foreign countries; eighty percent of the survey respondents confirmed it.

The pharmaceutical industry has proven to be influenced by public expenditure and R&D efforts. By maintaining communication and monitoring publicly funded research, pharmaceuticals build off of that knowledge to create innovative products with their own research. Building off of Acemoglu and Linn's research (2004) to understand the effect of market size on pharmaceutical research, Toole (2011) investigates the effect of public research on private biomedical research investments. He assumes a Poisson distribution of private R&D and uses several models to account for several aspects in determining the decision to invest. He builds on Acemoglu and Linn's research by examining the impact of public research investments on pharmaceutical innovation, which, according to his analyses, he showed to be positive. While admitting the complexity of the relationships and no direct relationship, his preferred model implies a 1% increase in the stock of public research is associated with a 1.8% increase in the number of new molecular entity applications after a substantial lag.

Research has also been done regarding the interaction between researchers at different institutions. Cockburn and Henderson (1998) sought to understand the relationship between this interaction and private research productivity (essentially, innovation) by collecting data on co-authorship within various institutions under the assumption that this is evidence of opportunities for extensive discussion, debate, exchange of ideas, and joint problem solving: something that reflects a significant investment on the part of the firm. They matched the co-authorship data to data on 10 firms' research performance and other measurable variables. Then, they established a statistical link between firms' choice of type of coauthor and the ways in which they organize the research function and, subsequently, tested for an association between these choices and research performance. They conclude that a firm's level of "connectedness" to publicly funded research in pharmaceuticals is positively and significantly associated with firms' internal organization and a firm's performance in drug discovery, implying an increase in innovation and a substantial return to public investments in basic research.

Pray and Nagarajan (2013) show that Indian agriculture firms' R&D expenditure is positively related to firm size, ownership by multinationals, ability to obtain patents, declining concentration and being in the seed industry. They use a unique data set for 5 years between 2000 and 2009. They determine the correct estimator to be a random effects model, using a Hausman test, utilizing data for variables including sales, the ability to patent, public partnerships, ownerships, firm diversification, concentration ratios, and time effects. Their results show that firms' sales are the major factor influencing R&D expenditure.

Hu et al (2011) explore how recent policy changes, particularly public R&D funding and liberalization of the input industry, induced more private R&D investments in the Chinese agriculture industry. Regarding public funding, Hu et al examined the impact of both research and development, as two separate entities, on firm-level private agricultural R&D investment. They used variables for privatization, public-research, public-development, policy support (in the form of public funding), firm-level characteristics (including sales and age), and industry and province variables. Their findings related to the impacts of public R&D investment on private research. Upon separating R and D, Hu found a statistically significant positive coefficient for Public R indicating that public research stimulates ideas that form the foundation for more advanced research in the private sector. Public D was negative indicating that development beyond the basic research level ends up crowding out private investment in agriculture, at least in China.

Alessio and Maietta (2008) sought to understand the determinants of innovation in the Italian food industry. They used a bivariate probit regression to estimate the impact of firm characteristics and structures on the presence of domestic firm R&D. They separate R&D expenditure into two categories: R&D spent within the firm, intra moenia and R&D spent external to the firm, extra moenia. They find the highest determinants for domestic firm R&D have been subsidies for R&D external to the firm.

Yahong Hu (2012) adapts Toole's framework to measure the impact of several variables on R&D research in China in addition to the impact on patents. She employs a random effects Tobit model to control for the high frequency of zero R&D in the dataset. Her empirical results showed that government R&D subsidies increase the private agricultural R&D investments and private R&D investments increase innovation.

Sanguinetti (2005) uses panel data on Argentine firms and a "Schumpeterian" framework to test the hypotheses that R&D expenditure in Argentina are affected by 1) firm size and 2) market power. He employs a fixed effects estimator to control for unobservable characteristics of firms. He shows that these hypotheses are consistent with the Argentine data. He finds that both variables are significant and positive and this result is robust to different econometric techniques, different sampling, and also survives when he includes industry characteristics and sector dummies. He also finds that foreign capital participation raises the level of both R&D and innovation expenditures. Finally, he evaluates the impact of an Argentine public sector program and its impact on R&D activities in the private sector. In order to account for a selection bias (as the public program might be targeting firms that will invest in R&D anyway), he performed a Difference in Difference estimation to evaluate this relationship. He finds this relationship to be positive and significant.

David, Hall, and Toole (2000) list four variables that impact a firm's cost of capital investment in R&D. First, technology policy measures affect the private cost of R&D projects. These policies may include tax treatment of R&D expenditure, R&D subsidies, and arrangements where government procurement agencies share in the cost. Second, there are surrounding macroeconomic conditions that could affect the internal cost of funds. A firm's price-earnings ratio in equity markets would likely affect decision making within the firm. A low price-earnings ratio will usually reflect low investor confidence which could deter R&D spending altogether. (No price-earnings ratio means a firm is losing money which would likely ruin any chance of R&D expenditure unless they are a start-up company running on venture capital.) Third, the bond market's conditions will affect the cost of gathering funds using external funds from lenders and other capital acquisition specialists. Finally, the availability and terms of venture-capital finance, as influenced by institutional conditions and the tax treatment of capital gains, will also affect a firm's ability to get external funds.

Toole (2007) followed the framework used by David, Hall, and Toole (2000) which postulates that the level of investment is determined by the interaction between the marginal cost of capital (MCC) and the marginal rate of return (MRR). His research determined the effects of the growth rates of several variables on pharmaceutical industry R&D investment. He accomplished this by using the log-difference estimator for all data sources which made the pharmaceutical R&D series weakly dependent and thus justified the use of IV regression and ordinary least squares. The variables used were the log of sales revenue (lagged by 1 year), distributed lags (extending 9 years) of the logs of public basic research and clinical research investment, the log of the FDA regulatory delay, a vector of the log of measures of drug demand, along with unobserved effects, time dummies, and an error with standard properties. Along with other findings, the empirical analysis found strong evidence that public clinical research is complementary to private pharmaceutical R&D investment and thereby stimulates private investment.

A paper that took a different approach, while indirectly adding to David, Hall, and Toole (2000), was Misra (2011). Misra set out to understand the relationship between R&D and market risk in India. She estimated market risk by regressing stock returns of firm i on BSE-Sensex returns using the monthly return from 2005 to 2009. She then regressed several financial variables, R&D intensity, and other explanatory variables on market risk, the dependent variable, using ordinary least squares. The coefficient of the degree of leverage was positive, indicating that the firms which have relatively low degree of leverage have lower market risk than the firms which have a relatively high degree of leverage. She concluded that after controlling for accounting variables which influence market risk, an increase in firm R&D intensity lowers the market risk of the firms in the different Indian industries. Although R&D expenditure was not the dependent variable, this paper is relevant for this literature review as she used the debt-equity ratio, a measure of leverage, as a determinant for the riskiness of a company. Since a lower amount of leverage is associated with a lower market risk, and a higher R&D intensity is associated with a lower market risk, there is reason to suspect that leverage is negatively associated with R&D, potentially indicative of a higher cost of capital investment when leverage is higher.

Chapter 4:

Conceptual Framework

Economic theory dictates that a firm, assuming other things equal, will produce a quantity to maximize profit based on where marginal cost meets marginal revenue and yield a profit maximizing equilibrium. David, Hall and Toole (2000) applied the basic profit maximizing condition of MC=MR to the R&D setting to understand the effects of public R&D and other variables on private R&D.

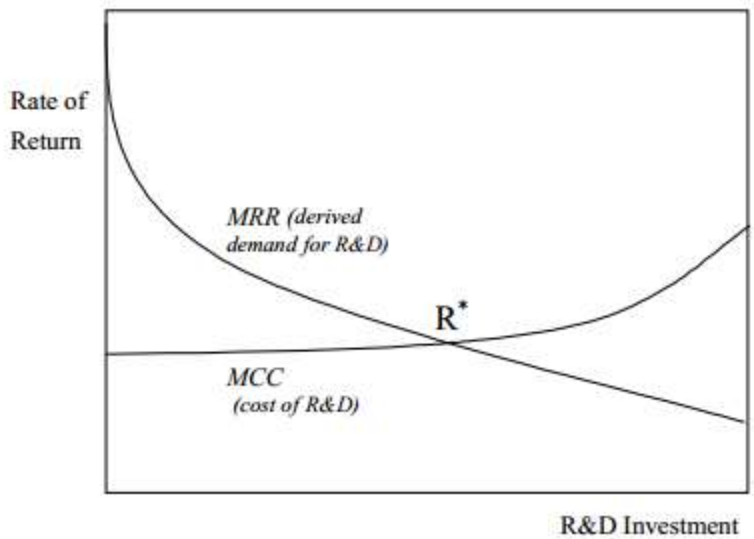
Instead of the generic marginal cost, within the R&D setting where R&D is considered a capital investment, David, Hall, and Toole looked at the marginal cost of capital (MCC) which reflects the opportunity cost of investment funds at different levels of R&D investment. Likewise, marginal revenue becomes the marginal rate of return (MRR) of the capital investment in R&D. We now have the following equation:

$$MRR = MCC$$

The shape of the equations and their respective elasticities should also reflect economic theory. The graph below shows a theoretical depiction of MRR and MCC. MRR will be more inelastic at lower levels of R&D investment because the first bit of R&D spending will have the greatest impact on R&D performance and thus a higher rate of return. It will then quickly drop off to a more consistent decline in the rate of return due to the law of diminishing returns, creating an overall downward slope.

MCC is also depicted in the figure below. It is more elastic at lower levels of R&D expenditure because the firm will use funds already allocated toward the R&D first, representing a very low opportunity cost. The MCC is upward sloping due to the increasing opportunity cost of diverting funds toward R&D research. If external financing increased, however, then the MCC curve would shift to the right as the internal opportunity cost of capital would increase at higher amounts of R&D.

Figure 2. MCC=MRR concept



The nature of what determines the profit maximizing level of investment (R*) is discussed at length in the literature review. As Pray and Fuglie (2000) delineated, there are three factors that impact a firm's MRR besides the R&D investment (R): 1) The size of the market, 2) technological opportunity, and 3) the appropriability of the innovation benefits. These three factors will be abbreviated as X. Hence, our MRR equation becomes:

$$MRR = f(R, X)$$

Similarly, David, Hall, and Toole (2000) delineate the factors that influence the MCC: 1) technology policy, 2) macroeconomic conditions affecting internal cost of funds, 3) macroeconomic conditions affecting external cost of funds, and 4) the availability of venture-capital financing and capital gains taxation. These four factors will be abbreviated as Z which yields a new MCC equation:

$$MCC = g(R, Z)$$

Hence,

$$f(R,X) = g(R,Z)$$

Utilizing our original assumption that the profit-maximizing level of investment in R&D (R*) is obtained at the intersection of MCC and MRR, we arrive at the final equation combining all factors involved in both the MCC and MRR:

$$R^* = h(X,Z)$$

Pray and Nagarajan (2013) used variables including sales, the ability to patent, public partnerships, ownerships, firm diversification, HHI, and time effects. These can be used as our X variables, which creates the following for our MRR:

MRR= f(R&D, sales, ability to patent, public partnerships, ownerships, firm diversification, HHI, and time effects)

For the MCC, using David, Hall, and Toole (2000) framework, I make several adaptations for this model. In order to capture surrounding policy measures (what David calls "technology policy") that could affect a firms cost of capital, I use the annual amount of subsidies and grants. This will act as a proxy for the government's role and influence in firms' R&D expenditure.

Although David, Hall, and Toole (2000) uses the price-earnings ratio in his framework to reflect investor confidence, the debt-equity ratio encompasses not only investor confidence but also the riskiness of the firm. If a firm has a high debt equity ratio, it is financing its growth aggressively with debt. If the cost of this debt outweighs the return that the company generates on the debt through investment and business activities, the business could go bankrupt leaving shareholders with nothing. The firm, acting on behalf of its shareholders and the fear of bankruptcy, will determine its ability to use funds to invest in R&D by looking at its debt-equity ratio. If the debt-equity ratio is too high (or higher than the firm's shareholders' preferences), the firm would likely cut back on R&D and would be reluctant to engage in aggressive investment. Hence, the debt-equity ratio can be conceptualized as a proxy for the opportunity cost of investing in R&D.

As David, Hall, and Toole (2000) note, the bond market's conditions will affect the cost of gathering funds using external funds from lenders and other capital acquisition specialists. To capture the macroeconomic conditions surrounding a lender's decision to offer funds, I include the average interest rate (lending rate) for each year.

As a proxy for capital availability, and a reflection of the availability and terms of external financing within the lender, I use the total amount of borrowings of the firm per year from all financial institutions. A higher borrowing amount should reflect a higher investor confidence (or else they would be reluctant to lend) and an environment more conducive for R&D expenditure (as there is a lower opportunity cost when external financing is available). Including the available variables in our analysis, our MCC evolves:

MCC= g(R, Interest Rates, Borrowings, Subsidies & Grants, Debt Equity Ratio)

However, attempts at using both the annual Borrowings and Debt Equity Ratio of the firm in one model have proven to be troubling theoretically. Although the two variables are different by definition, there is too much conceptual overlap between the two as both relate to the debt of a firm. Hence, I have instead used Debt Equity Ratio and its square in one model and Borrowings and its square in the other models.

As the pesticide industry has experienced more policy changes regarding intellectual property rights, I have included a policy dummy for firms in the pesticide industry for years 2005-2009. This will allow for controlling for policy differences between industries and understanding the impact of intellectual property rights in this analysis.

In addition to using R&D expenditure as the dependent variable, I also use R&D intensity for another model. R&D intensity is calculated as R&D expenditure as a fraction of total sales. The literature on R&D often uses R&D intensity instead of R&D because the sales variable can explain so much of the variability of R&D that the impact of other variables may be obscured. Hence I include both to create a better understanding of the variables affecting Indian R&D.

Chapter 5:

Data Description

The dataset used for this analysis comes from a few sources covering the fertilizer and pesticide industries. Prowess, a database of The Centre for Monitoring Indian Economy (CMIE), compiles data from annual financial reports of Indian companies from 1989-90 until present day. The bulk of the data used in this analysis is from a CMIE spreadsheet which includes years 1989 through 2007. However, if this source was used alone, the panel would be extremely unbalanced because it would not include firms from the seed and agricultural machinery industries. In addition, it did not have data on interest rates and ownership dummies. Hence, survey data gathered by Pray and Nagarajan (2013) was used to supplement this data which helped to fill in the blanks on other industries and ownership differentiation. Finally, data on Indian interest rates were gathered from the International Monetary Fund (IMF). The HHI was calculated by the author using available data from the CMIE.

In total, there are 91 firms over the course of 21 years (1989-2009) with data more complete for some variables and years than others. Originally, the analysis included the seed and agricultural machinery firms. However data on the cost variables was available for only the fertilizer and pesticide firms. Hence, I was forced to exclude the seed and machinery industries from the empirical analysis. Each firm’s respective industry is specified using dummy variables. Other dummies further identify if the firm is a public or private enterprise, or a multinational corporation.

Chapter 6:

Empirical Model

Based on the conceptual framework, the background of R&D in India, and the previous literature, the following empirical model is formulated for the R&D investment model:

General Least Squares Random Effects Model

$Y_{it} = \alpha + \beta X_{it} + u_{it} + \varepsilon_{it}$

The justification for using random effects is threefold: 1) There is good reason to believe differences across Indian firms have an influence on R&D. Because there are big differences in investments between industries, random effects is more appropriate conceptually. On top of that, the data has been transformed so that independent variables are not correlated, as this is a crucial assumption of the random effects model. 2) Due to the number of time-invariant variables in this analysis, random effects is advantageous. Otherwise, these effects would be absorbed by the intercept. The random effects model assumes that the entity's error term is not correlated with the predictors which allows for time-invariant variables to play a role as explanatory variables. The need to specify individual characteristics that may or may not influence the predictor variables has been accomplished through the use of industry specification and other dummy variables. Of course, if the explanatory variables are not specified thoroughly, the model could suffer from omitted variable bias, which would be addressed in later sections 3) Additionally, I also considered the Fixed Effects model which could have been more appropriate for the data. To determine the correct model, I conduct a robust Hausman Test for each model which essentially tests whether the unique errors (ui) are correlated with the regressors; the null hypothesis is they are not. I could not reject the null hypothesis that the differences in the coefficients between the random and fixed effects models were systematic. The result of the test was insignificant. Hence, random effects is once again the more appropriate model.

It is also important to understand the variable transformations that were done to make certain variables meet the assumptions of linear regression, specifically the issue of normality. The residuals of all of the variables should have a normal distribution. The log of total sales amount and age of a firm was used to normalize the residuals of these variables. In addition, both borrowings and borrowings-squared were used to help explain both aspects of the residuals to be sure of a complete analysis.

The 4 primary models of interest with their respective variable changes become:

(M1A) **R&D expenditure$_{it}$ = α_0 + $\alpha_1$logsales$_{it}$ + α_2 logage$_{it}$ + $\alpha_3$subsidies&grants$_{it}$ + $\alpha_4$borrowings$_{it}$ + $\alpha_5$borrowings$_{it}^2$ + $\alpha_6$interest rate$_{it}$ + α_7 HHI$_{it}$ + α_8 Industry dummies$_{it}$ + α_9Ownership dummies$_{it}$ + α_{10}IPRpolicy dummy$_{it}$ + λ_{it} + μ_{it}**

(M1B) **R&D expenditure$_{it}$ = α_0 + $\alpha_1$logsales$_{it}$ + α_2 logage$_{it}$ + $\alpha_3$subsidies&grants$_{it}$ + α_4 debt-equity ratio$_{it}$ + α_5 debt-equity ratio$_{it}^2$ + $\alpha_6$interest rate$_{it}$ + α_7 HHI$_{it}$ + α_8 Industry dummies$_{it}$ + α_9Ownership dummies$_{it}$ + α_{10}IPRpolicy dummy$_{it}$ + λ_{it} + μ_{it}**

(M2A) **R&D Intensity$_{it}$ = α_0 + α_2 logage$_{it}$ + $\alpha_3$subsidies&grants$_{it}$ + $\alpha_4$borrowings$_{it}$ + $\alpha_5$borrowings$_{it}^2$ +$\alpha_6$interest rate$_{it}$ + α_7 HHI$_{it}$ + α_8 Industry dummies$_{it}$ + α_9Ownership dummies$_{it}$ + α_{10}IPRpolicy dummy$_{it}$ + λ_{it} + μ_{it}**

(M2B) R&D $Intensity_{it} = \alpha_0 + \alpha_2\, logage_{it} + \alpha_3 subsidies\&grants_{it} + \alpha_4$ debt-equity $ratio_{it} + \alpha_5$ debt-equity $ratio_{it}^2 + \alpha_6$interest $rate_{it} + \alpha_7\, HHI_{it} + \alpha_8$ Industry $dummies_{it} + \alpha_9$Ownership $dummies_{it} + \alpha_{10}$IPRpolicy $dummy_{it} + \lambda_{it} + \mu_{it}$

where

R&D $expenditure_{it}$: In millions Rupees, from annual financial reports compiled by the CMIE from 1989 to 2009. It is the dependent variable for this analysis and the average annual R&D expenditure of firm i.

R&D $Intensity_{it}$: Calculated by the author, it is R&D as a percentage of sales. (R&D/Sales *100)

$Sales_{it}$: In millions Rs, from annual financial reports compiled by the CMIE from 1989 to 2009. It is the the average annual sales revenue of firm i.

Firm Age_{it} : Age of firm i. Incorporation year of the firm has been taken as the measure of age of firm i. Source of data has been individual company reports. It has been included as a control variable.

Government Subsidies & $Grants_{it}$: In millions Rs, from annual financial reports compiled by the CMIE from 1989 to 2009. It is the average amount of subsidies or grants firm i received by the government. It has been included as a control variable.

$Borrowings_{it}$: In millions Rs, from annual financial reports compiled by the CMIE from 1989 to 2009. It is the average amount of borrowings firm i received from financial institutions, regardless of the type of borrowing. It has been included as a control variable.

Debt-equity ratio$_{it}$: Calculated as a firm's total liabilities expressed as a fraction of the shareholders' equity. It is the average leverage of firm i from annual financial reports compiled by the CMIE from 1989 to 2009. It has been included as a control variable.

Interest Rate$_{it}$: The average lending rate, for each year, from the International Financial Statistics database as part of the IMF. It has been included as a control variable.

HHI$_{it}$: Calculated by the author using CMIE data from 1989 to 2009 for each of the 4 industries. Some years have been excluded due to the dataset's unbalanced nature and lack of enough sales observations over time. It has been included as a control variable.

Industry Dummies$_{it}$: 2 categorical variables describing the industry of a firm. Listed as 1 (yes) or 0 (no) for pesticide and fertilizer. Taken from Pray and Nagarajan's survey work (2013) and the CMIE. They are included to control qualitative features of the data.

Ownership dummies$_{it}$: If a firm is publicly owned, privately owned, or a multinational corporation, it is listed as a 1 (yes) or 0 (no). Taken from Pray and Nagarajan's survey work (2013) and the CMI. In addition, a dummy variable describing firms that engage in both pesticide and fertilizer has been included in the analysis. They are included to control qualitative features of the data.

IPR $dummy_{it}$: Due to advances in the pesticide industry, this variable has only been applied to firms in the pesticide industry. It is listed as a 1 (yes) or 0 (no).

The direction of the relationship between the control variables and R&D expenditure depend upon the estimated values of the coefficients. Based on the conceptual framework adapted from David, Hall, and Toole (2000), and the results of other related literature, we can expect certain relationships between the dependent and independent variables in this analysis. If the estimated coefficient for sales comes out to be positive (negative) and significant, it means that firms that enjoy higher sales are investing more (less) in R&D than firms which have relatively low average sales numbers. Previous analyses (Pray and Fuglie 2000) have produced positive relationships between sales and R&D in India, and I expect similar results.

Firm age was used as a control variable in Misra's analysis (2011) of the relationship between market risk and R&D. If it comes out to be positive (negative) and significant, it would mean the relatively old-aged firms are investing more (less) in R&D than relatively new firms. Misra's coefficient on firm age was positive but insignificant. There is no good reason to expect firm age to affect R&D negatively or positively, however there is literature that used the variable as a control.

In order to capture surrounding policy measures, what David calls "technology policy," that could affect a firm's cost of capital, I use the annual amount of Government subsidies and grants. This will act as a proxy for the government's role and influence in firms' R&D expenditure. If the estimated coefficient for subsidies & grants comes out to be positive (negative) and significant, it would mean that firms that receive relatively higher levels of public funding are investing more (less) in R&D than firms that are relatively less publicly funded. Based on David's framework, a government's policies toward R&D will either encourage or deter R&D. I expect the relationship to be positive as a higher level of subsidies and grants would indicate a more supportive technology policy of the government.

A firm's ability to receive financing and a lender's ability to offer external financing for a firm, described by David, Hall, and Toole as a cost of capital investment, can be reflected by using the annual amount of borrowings from all financial institutions. If the estimated coefficient for borrowings comes out to be positive (negative) and significant, it would mean that firms more actively funding their business with debt are investing more (less) in R&D than firms that are borrowing less from financial institutions. I expect borrowings to be positively related to R&D as higher levels of borrowings should reflect an easier environment to acquire capital.

As discussed earlier, a firm, acting on behalf of its shareholders and the fear of bankruptcy, will in part determine its ability to use funds to invest in R&D by looking at its debt-equity ratio. (Misra 2011; David, Hall, and Toole 2000) A higher debt-equity ratio means that the firm is leveraging its operations externally which would free up funds for R&D expenditure. Hence, I would expect the relationship to be positive. If the debt-equity ratio is too high (or higher than the firm's shareholders' preferences), however, the firm would likely cut back on R&D and would be reluctant to engage in aggressive investment. For this reason, a square term has been included to account for the threshold where the opportunity cost of investing in R&D becomes too high. Based on Misra's analysis, a higher debt-equity ratio puts a firm at greater risk of bankruptcy.

Hence, I expect the relationship between R&D and debt-equity ratio-squared to be negative.

As delineated in the conceptual framework, the bond market's conditions will affect the cost of gathering funds using external funds from lenders and other capital acquisition specialists. To capture the macroeconomic conditions surrounding a lender's decision to offer financing, I include the average interest rate (lending rate) for each year. If the estimated coefficient for interest rate comes out to be negative (positive) and significant, it would mean that firms that enjoyed lower interest rates are investing more (less) R&D than firms that faced higher interest rates across time. I expect the relationship between R&D and interest rates to be negative.

The relationship between market concentration and R&D has been explored at length by previous literature. Although the topic is vast and only touched upon here, in some of the literature reviewed (Sanguinetti 2005; Pray and Nagarajan 2013), a variable for market concentration was utilized as a control. These studies have found a positive relationship between higher market concentration and R&D. Based on critiques of previous analyses, I have used the HHI as a measure of market concentration. If the estimated coefficient for HHI comes out to be positive (negative) and significant, it would mean that firms in industries with higher levels of market concentration are investing more (less) in R&D than firms in other industries. Based on previous literature, I expect the relationship between R&D and HHI to be positive.

Chapter 7:

Empirical Results

As stated earlier, the purpose of this paper is to understand the determinants of R&D using a conceptual framework that incorporates both variables that affect the marginal rate of return of capital investment and those that affect marginal cost of capital investment and other instrumental variables to control the analysis.

First, I compare summary stats by industry and by ownership. Previous analyses have shown that private firms will generally invest in more R&D than their public counterparts. The data I have used supports such claims. The table below shows summary statistics for public firms and private firms from this dataset.

R&D expenditure is on average much higher for private firms regardless of other classifications at 49.88 million Rs compared to 8.75 million Rs for public firms. In addition, their sales numbers aren't that different which means that other differences are at work here. A firm's leverage, measured by the debt-equity ratio, is starkly higher for private firms. Not only does this show a more aggressive stance towards R&D investment in the private sector, as a higher debt-equity ratio reflects a higher market risk, but also a higher level of accessibility to venture capital, as lenders will decide to offer financing in part based on the debt-equity ratio. Interestingly, total borrowings from all institutions were higher for public firms. This may reflect institutional advantages that government owned corporations have in accessing credit from government owned banks and other factors outside the scope of this analysis.

When we compare the fertilizer industry with the pesticide industry, we can see how the cost of capital affects specific industries differently.

Table 2. Summary statistics: private firms

	Summary Statistics- Private Firms 1989-2009, n=77			
	mean	sd	min	Max
R&D expenditure (Rs. Millions)	49.88	102.15	0	1000
R&D intensity (R&D/Sales*100)	1.76	3.64	0	28.57
Debt/Equity Ratio (Liabilities/Equity)	3.74	32.73	-59.79	669.25
Age of firm (Years)	44.19	21.77	12	112
Borrowings (Rs. Millions)	2491.35	4503.53	0	23156.2
Subsidies & Grants (Rs. Millions)	0.89	2.52	0	19.2
HHI (Sum of Squares of Market Shares)	1352.17	614.49	500.96	2955.6
Sales (Rs. Millions)	4777.27	6762.76	0.6	62347.1

Table 3. Summary statistics: state owned firms

	Summary Statistics- State Owned firms 1989-2009, n=13			
	mean	sd	min	max
R&D expenditure (Rs. Millions)	8.75	20.91	0	107.1
R&D intensity (R&D/Sales*100)	0.08	0.13	0	0.51
Debt/Equity Ratio (Liabilities/Equity)	0.22	6.95	-64.45	38.08
Age of firm (Years)	46.31	8.1	33	59
Borrowings (Rs. Millions)	7370.56	8379.69	1.1	64933.3
Subsidies & Grants (Rs. Millions)	0.23	2.4	0	32.2
HHI (Sum of Squares of Market Shares)	1389.77	423.89	752.87	2955.6
Sales (Rs. Millions)	12839.97	29887.09	0.08	329484.3

Table 4. Summary statistics: fertilizer firms

	Summary Statistics- Fertilizer Industry 1989-2009, n=22			
	mean	sd	min	max
R&D expenditure (Rs. Millions)	14.78	28.8	0	237.4
R&D intensity (R&D/Sales*100)	0.12	0.19	0	1.62
Debt/Equity Ratio (Liabilities/Equity)	3.9	38.54	-64.45	669.25
Age of firm (Years)	49.51	16.01	23	94
Borrowings (Rs. Millions)	6890.18	7563.2	1.8	64933.3
Subsidies & Grants (Rs. Millions)	0.6	2.72	0	32.2
HHI (Sum of Squares of	1290	289	1045	2382

Market Shares)				
Sales (Rs. Millions)	1165	22809	0.08	329484

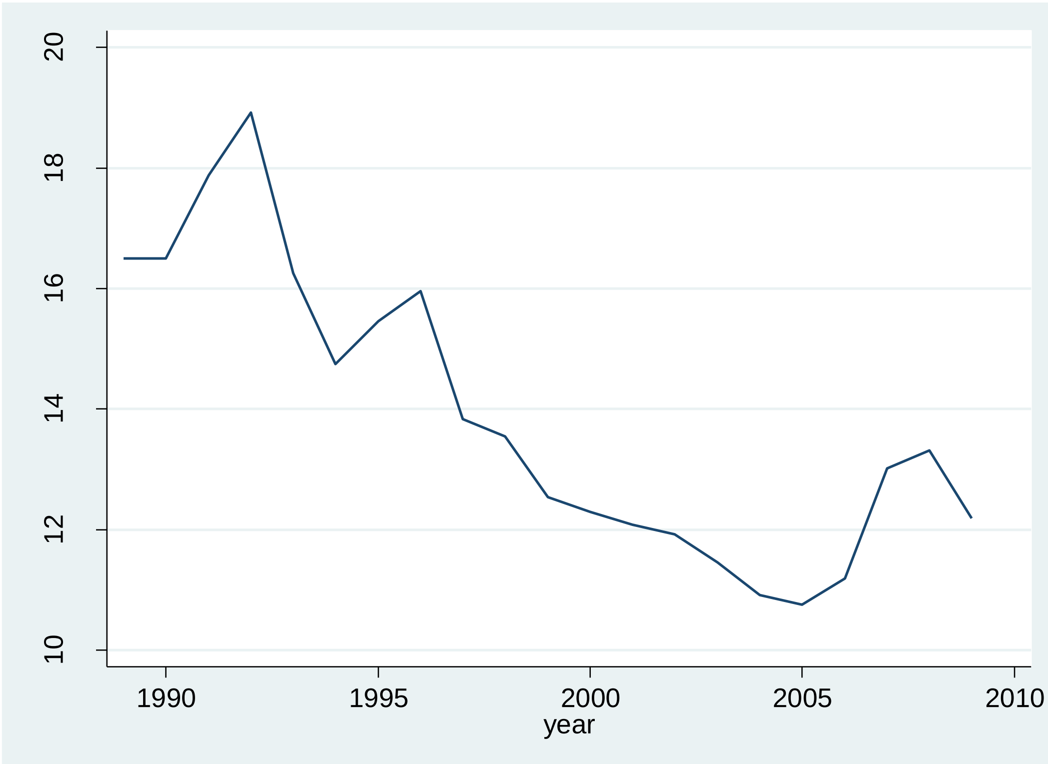
Table 5. Summary statistics: pesticide firms

	Summary Statistics- Pesticide Industry 1989-2009, n=23			
	mean	Sd	min	max
R&D expenditure (Rs. Millions)	32.5	65.71	0	672
R&D intensity (R&D/Sales*100)	0.6	0.65	0	3.5
Debt/Equity Ratio (Liabilities/Equity)	1.42	3.01	-18.04	23.29
Age of firm (Years)	47.04	19.22	13	112
Borrowings (Rs. Millions)	926.41	1683.31	0	19788.3
Subsidies & Grants (Rs. Millions)	0.72	2.31	0	17.5
HHI (Sum of Squares of Market Shares)	1707.12	644.08	752.87	2955.6
Sales (Rs. Millions)	2999	4191	0.13	48020

On average, firms in the pesticide industry spend over double the amount in R&D as their fertilizer counterparts. At the same time, the debt-equity ratio is higher for fertilizer firms, marking how differently certain industries react to higher levels of leverage. Of course, it is important to note that different industries have different debt-equity ratios simply as a result of being a different industry with different procedures, policies, and government involvement.

As shown in Figure 4, in terms of Indian interest rates, the cost of capital has decreased over time. Although there were various attempts at economic liberalization in India throughout the 1900's, it took a great turn for the better after the nation's balance of payments crisis in 1991, reflected by the spike in interest rates during that time. Since then, the government made implemented several policies encouraging international trade and investment, deregulation, initiation of privatization in many industries, tax reforms, and inflation-controlling measures. Economic liberalization allowed for a freer and looser financial system, one that allows companies to be more aggressive in financing their operations with debt while also providing capital availability under more forgiving regulations. Additionally, barriers to entry in agricultural industries have seemingly diminished as the market concentration, represented by HHI, has decreased. Firms' debt-equity ratio has, on average, increased, showing the system's increased ability to gather capital and a more aggressive stance when deciding to finance a firm's operations with debt. However, as shown by the empirical results of the regressions, this does not necessarily lead to an increase in R&D on average. Though to a lesser extent, the total borrowings of a firm has also increased, which fits into the pattern of looser financial standards when applying for loans. Finally, the amount of subsidies and grants have increased showing the governments increased support for business activity post-liberalization.

Figure 3. Interest rates in India over time, 1989-2009



The regression results of (1) and (2) are shown below. In model (1), as expected, sales positively affects a firm's R&D expenditure and is significant at the 1% level. Because it is a line-log regression, a one percentage increase in Sales, on average, results in an increase in R&D by Beta/100 units. Hence, a 1% increase in sales, on average, results in a 0.04 unit increase in R&D. This is no surprise as sales can act as an overall proxy for the amount of internal financing available for a firm. The more internal financing available, the less of an opportunity cost of capital investment, which allows for more R&D expenditure.

(M1A) **R&D Expenditure$_{it}$ = $\alpha_0 + \alpha_1$logsales$_{it}$ + α_2 logage$_{it}$ + $\alpha_3$subsidies&grants$_{it}$ + $\alpha_4$borrowings$_{it}$ + $\alpha_5$borrowings$_{it}^2$ + $\alpha_6$interest rate$_{it}$ + α_7 HHI$_{it}$ + α_8 Industry dummies$_{it}$ + α_9Ownership dummies$_{it}$ + α_{10}IPRpolicy dummy$_{it}$ + $\lambda_{it} + \mu_{it}$**

(M1B) **R&D Expenditure$_{it}$ = $\alpha_0 + \alpha_1$logsales$_{it}$ + α_2 logage$_{it}$ + $\alpha_3$subsidies&grants$_{it}$ + α_4 debt-equity ratio$_{it}$ + α_5 debt-equity ratio$_{it}^2$ + $\alpha_6$interest rate$_{it}$ + α_7 HHI$_{it}$ + α_8 Industry dummies$_{it}$ + α_9Ownership dummies$_{it}$ + α_{10}IPRpolicy dummy$_{it}$ + $\lambda_{it} + \mu_{it}$**

(M2A) **R&D Intensity$_{it}$ = $\alpha_0 + \alpha_2$ logage$_{it}$ + $\alpha_3$subsidies&grants$_{it}$ + $\alpha_4$borrowings$_{it}$ + $\alpha_5$borrowings$_{it}^2$ +$\alpha_6$interest rate$_{it}$ + α_7 HHI$_{it}$ + α_8 Industry dummies$_{it}$ + α_9Ownership dummies$_{it}$ + α_{10}IPRpolicy dummy$_{it}$ + $\lambda_{it} + \mu_{it}$**

(M2B) **R&D Intensity$_{it}$ = $\alpha_0 + \alpha_2$ logage$_{it}$ + $\alpha_3$subsidies&grants$_{it}$ + α_4 debt-equity ratio$_{it}$ + α_5 debt-equity ratio$_{it}^2$ +$\alpha_6$interest rate$_{it}$ + α_7 HHI$_{it}$ + α_8 Industry dummies$_{it}$ + α_9Ownership dummies$_{it}$ + α_{10}IPRpolicy dummy$_{it}$ + $\lambda_{it} + \mu_{it}$**

Table 6. Regression results (1989-2009)

Dependent Variable:	**R&D Investment Expenses (Rs. Mill)**		**R&D Investment Intensity (R&D/Sales*100)**	
Model:	**M1A**	**M1B**	**M2A**	**M2B**
	Coef (Robust Std)	Coef. (Robust)	Coef (Robust)	Coef (Robust)

Log of Sales (Rs. Mill)	5.948*** (1.79)	6.953*** (2.453)	--	--
Log of Age (years)	12.694 (11.918)	10.483 (10.627)	0.336 (0.221)	0.358 (0.223)
Borrowings (Rs. Mill)	0.006*** (0.002)	--	0.00003*** (0.00001)	--
Borrowings-Squared (Rs. Mill)	-9.17E-08*** (0)	--	-5.59E-10*** (1.92e-10)	--
Debt-Equity Ratio (Liabilities/Equity)	--	0.18 (0.14)	--	0.002 (0.002)
Debt-Equity Ratio Squared	--	-0.0001 (0.001)	--	-9.56E-06 (0.00001)
HHI (Sum of Squares of Market Shares)	-0.003 (0.003)	-0.004 (0.003)	-0.0001** (0.00004)	-0.0001*** (0.00004)
Subsidies & Grants (Rs. Mill)	-0.268 (0.655)	-0.152 (0.744)	0.003 (0.009)	0.002 (0.008)
State Owned Enterprise (1-yes; 0-privatized)	4.083 (10.778)	9.457 (10.261)	-0.045 (0.155)	-0.012 (0.127)
IPR Dummy (Years 2005-2009, Pesticide)	1.49 (4.966)	1.157 (6.958)	0.054 (0.079)	0.043 (0.088)
Industry Overlap (Fertilizer & Pesticide)	8.914 (10.489)	5.606 (10.513)	-0.059 (0.135)	-0.061 (0.132)
Fertilizer Dummy (1-yes; 0-other)	-53.563*** (17)	-24.223** (11.695)	-0.78*** (0.203)	-0.618***

				(0.182)
Interest Rate	-1.914** (0.914)	-2.066** (1.058)	-0.074*** (0.026)	-0.077*** (0.028)
Constant/Intercept	-44.613 (47.035)	-32.573 (41.301)	0.406 (0.808)	0.439 (0.812)
Number of observations for all time periods (1989-2009)	237	237	231	231
Wald $chi^2(11)$	48.46	37.06	--	60.97
Prob > chi^2	0.0000	0.0001	--	0.0000
R-sq: within	0.44	0.25	0.30	0.28
between	0.34	0.197	0.27	0.29
overall	0.41	0.3	0.27	0.26

Note: The asterisk, *, **, and *** indicates 10%, 5% and 1% significance level, respectively.

The coefficient for the age of the firm is insignificant in all 4 models. Although one would expect some kind of significance of the correlation between age and R&D expenditure, for our data, there is none. Seemingly, there is a high probability of seeing this same result in a collection of random data in which the variable had no effect.

The coefficients for borrowings and borrowings-squared are significant at the 1% level. As stated earlier, I include both borrowings and borrowings-squared in order to account for both parts of the curvature of the relationship between the amount of borrowings and R&D. The results show that borrowings has a positive relationship with R&D, supporting the concept that an increase in external financing shifts the opportunity cost of investing in R&D downward to the right, thereby allowing for more R&D expenditure. In addition, borrowings-squared is negatively related which supports the idea that when the total borrowings increases to a certain threshold, the firm will be more reluctant to invest and more inclined to pay off its debt.

The debt-equity ratio, a measure of leverage, was insignificant in all 4 models. As stated earlier, the variable shows the leverage a firm has received and the riskiness of a firm. A higher amount of debt as a fraction of shareholder equity might deter a firm from investing in R&D which is a long term risky investment as they would not like to increase their risk of bankruptcy. Although it is theoretically sound to include the variable, for this data and model it was insignificant.

The coefficient for the amount of subsidies and grants a firm receives is not significant in all 4 models, perhaps due to the unbalanced nature of the variable. As shown above, prior to 2000, most firms received little to nothing in the form of subsidies. However, after liberalization, there was much more government support.

The coefficient for HHI, a measure of market concentration, is significant in M2A and M2B, the R&D Intensity models. The fact that the relationship between market concentration and research and development is negative shows that Indian firms have been motivated to invest in R&D when there are higher levels of competition. The concentration may have declined due to the increased entry of multinational corporations such as Bayer and Monsanto.

The coefficient for the interest rate (lending rate) was significant at the 5% level in M1A and M1B, where R&D expenditure is the dependent variable, and significant at the 1% level in M2A and M2B. The negative relationship supports the notion that higher rates on loans would increase the cost of gathering external financing, thereby decreasing R&D expenditure.

The coefficients on the dummy variables show the contrast between different industries and types of ownership. Compared to other industries, the fertilizer industry is heavily associated with a lack of R&D expenditure. In addition, publicly owned companies invest less in R&D likely due to little incentive and stricter budgetary concerns.

Chapter 8:

Discussion and Conclusion

Understanding the mechanism of innovation is essential for industrial progress and public policy. Agricultural innovation is not only essential for these two entities, but consumers as well. Although there is some literature documenting the effect of revenue-related variables, there is far less focusing on the cost of investing in R&D and how financial variables might affect the opportunity cost of investing in R&D. While most studies focus on revenue-related aspects, we chose a somewhat different approach to understand how financial variables might affect a firm's decision to invest in R&D. Using a conceptual framework that incorporates aspects of cost, we have analyzed how certain variables that fit into the framework might affect R&D expenditure.

There are several observations we can make about Indian firms and R&D through the years 1989 to 2009 from this analysis. We can say that the sales of a firm affects R&D heavily and the decision to invest will be largely based on its revenue stream. This is hardly a novel conclusion as all of the economic literature has arrived at similar conclusions.

Venturing into the more unique aspects of this analysis, the cost variables offer some insight into how Indian firms react to various types of costs. Debt plays an intriguing role in a firm's decision to invest. The contrast in the signs of borrowings and borrowings-squared, offers insight into how debt affects the cost of R&D. At first, one might presume that the more borrowings a firm can obtain, the less financing from within the firm is necessary and will increase R&D expenditure. This is true to a point as the sign for borrowings is positive. After a certain threshold however, as shown by borrowings-squared, R&D begins to decrease. This shows that once a firm goes into a certain amount of debt, the cost of investing more is too great and will deter investing in R&D. The negative coefficient on debt-equity ratio, leverage, supports this claim as well. In addition, how the cost of capital investment affects that decision, is heavily industry specific. It is well known that normal levels of debt-equity ratio depends greatly on the industry. Some industries are more accustomed with higher debts and higher risk of bankruptcy which is why further research is needed to more fully understand how different industries react to higher debt.

The relationship between cost variables and R&D is small which is why one should take these results as a basic introduction to a relatively unexplored region of R&D research. In addition, to make the results more accurate and a more fluid analysis, a balanced panel would help greatly. Although using an unbalanced panel was sufficient to extrapolate results and discussion, a balanced panel would be ideal and would allow a more nuanced discussion of the effects over time. The decision to use these variables is according to my interpretation of the economic literature, however another author might choose to use other variables and get different results. In conclusion, my research supports the notions that cost variables play a role in affecting R&D and, in the Indian context, economic liberalization of the nation's financial markets has reduced that cost, creating more opportunities for investment in R&D. My hope is that this thesis can inspire at least one other person to take this approach to higher levels and increase our understanding of the life-blood of innovation.

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