Patterns of Success in the Indian Software Industry

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Senior Honors Thesis
completed under the direction of
Professor Frank Wolak
Abstract

The software industry in India has been growing at phenomenal rates over the last ten years. Currently a 17.15 billion rupee ($560 million) industry, it has experienced compound annual growth rates of over 40-50%. Based on interviews of Indian government officials and over 35 CEOs and managers of Indian software firms and econometric analysis of over 190 firms in the industry, this paper provides simple frameworks to understand the start, growth and evolution of this industry. It focuses on the behavior and incentives of both the potential clients of the software industry and the Indian firms. By understanding this behavior, we can understand why some Indian software firms grew and gained large degrees of market power while others did not. These frameworks will then provide a context for analyzing actual firm and customer behavior in the software industry.

Traditional comparative advantage models only provide superficial explanations for understanding the growth of the Indian software industry. We must evaluate the industry beyond the basic assertion that western firms wished to take advantage of the wage differential existing between Indian software firms and western software firms. This does not sufficiently explain the imperfectly competitive nature of the industry and the rise of some Indian firms and stagnation of others. In order to understand this behavior, one must look at the transaction costs involved in using an Indian software company rather than a local, domestic one. Potential clients incur an additional search cost in trying to find a company that satisfies their needs and Indian firms must find methods to reduce this search effort. This paper examines specifically how Indian firms have managed to do this through market signaling. Then, econometric analysis will provide an examination of the relative impact of these methods on individual firm growth.

This study has important implications for understanding the growth of technology industries in developing countries. It provides an understanding of what these firms with a global view can do to grow in the international marketplace. Understanding this allows governments to design effective policies to help firm level growth which then translates into overall industry growth.
Acknowledgments

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Finally, I would like to thank my parents who I know, no matter what anyone says, will like this paper.
What kind of industries develop in third world countries? Westerners often see visions of the poor, unskilled third-world laborer working for meager wages in work such as textile weaving or simple machine assembly. Workers toil for long hours and take jobs away from westerners because of the lower labor cost brought on by the high population driving down the equilibrium wage. Because of this, one would expect developing countries to export low technology, labor intensive products. This makes sense within the economic theory of comparative advantage. Countries export the goods and services in industries in which they are relatively better at producing. Developing countries with their overpopulation of unskilled labor should be relatively better at sectors that require these laborers and as a result, they export goods and services in these industries (Caves, Frankel, and Jones 1996). Since the work requires unskilled labor and little technology investment, the industry structure is usually extremely competitive in nature and a large number of small firms earn minimal profits. The ease of entry and exit causes the competing away of most profits and the lack of dominance of any one firm. Developing countries have more or less followed this comparative advantage trade model over most of history. For example, India primarily exports ready-made garments, gems, and leather goods. All these goods require production factors in which India is relatively well endowed.

However, if a developing country has a large number of skilled labor in fields such as science and engineering, can this model be applied in the same manner? If so, westerners will see a profit opportunity in using this large population since their equilibrium wage is lower. High technology industries provide the best possible allocation of this skilled labor since these industries require engineering talent. This presence of skilled labor explains the recent rise of high technology industries in certain developing countries. When western firms see a profit opportunity in using the low-cost technical talent, they find a method to use this talent. From the viewpoint of the
developing country, people can profit by exporting the services of this talent to other countries.

Therefore, a straightforward application of this model may seem to explain the recent rise of the Indian software industry. Simply put, the Indian government has devoted many resources to university technical education which produced a large amount of technical talent. This drove down the equilibrium wage in India, and foreign companies took advantage of this differential to increase profits. Although this may explain the industry on a superficial level, it does not help us understand deeper questions regarding the evolution of the industry. We still need to examine how the current industry structure evolved and why some companies grew and gained large degrees of market power while others did not. To understand these questions, one must explicitly reexamine the fundamental assumptions of these models. These traditional economic models assume zero transaction costs when trading internationally. However, transaction costs seem to play a large role in the success of firms in the industry. These costs involve asymmetric information between the foreign customers and the Indian firms. Asymmetric information occurs because foreign firms do not have complete knowledge of the Indian firms and their abilities. Therefore, they incur additional costs in "searching" for the right company for their needs when trying to take advantage of the wage differential. Economists often take these costs to be zero or assume them to be negligible. However, this paper will argue that they actually play a crucial role in understanding the Indian software industry. If these costs are too high, it may not be worthwhile for foreign companies to use an Indian company for their software work. Then, a mutually beneficial transaction will fail to occur (North 1989).

According to traditional comparative advantage models, western firms would import this Indian talent individually. Early in the development of the industry this practice known as "bodyshopping" prevailed but now has decreased due to increasing regulation by western countries and India (Hass 1992). Other problems also occur in
importing this talent from the standpoint of the western firm which increases the cost of doing this. Trying to find the people in India who have the relevant skills and knowledge that the western companies need incurs additional costs. As well, companies may also suffer the risk that the person will not fit in with the nature of their work and culture. In addition, the western company may find it difficult to assemble a team of engineers from India who have a diverse set of skills. Once the engineers come from India to the western country, employers may not find it feasible to pay them differentially from everyone else.

The creation of Indian software firms provides the solution to these problems. Western firms can shift these transaction costs to the Indian firms and they take responsibility for managing and assembling the software talent. This also maintains the wage differential existing between the two countries. To formalize this idea of the creation of firms to lower transaction costs, Milgrom and Roberts (1992) show that a firm can minimize both the coordination and motivation costs of the transactions between the two countries. A firm minimizes coordination costs by better organizing the talents of the skilled workforce and using them in a more efficient manner than if they worked as individuals. A firm also decreases motivation costs that arise from the information asymmetry existing between the workforce in the developing countries and the western clients. This information asymmetry arises because the companies in developed countries may not have all the information that they need to determine whether the people in the developing country will satisfy their needs. Even with firms, the western clients have to incur search costs to find the Indian company that satisfies their needs but finding firms involves lower transaction costs than finding individuals. Part of this reduction occurs because Indian firms provide signals of their abilities to the overseas customer so that they will feel comfortable using the company. If they did not, foreign companies may fear the uncertainty of knowledge about Indian software firms and may not use them especially in high technology projects that may be crucial to the eventual functioning of their organization. The nature and impact of these costs differ between organizations according
to the type of sectors that the firms work in and the nature of the transactions. However, when looking at the Indian software industry with its customers in developed countries, this paper will argue that high motivation costs from information asymmetry exist and successful firms in these types of industries must organize themselves to minimize these types of transaction costs as much as possible in order to grow and gain larger degrees of market power.

In the first section of the paper, I will provide the relevant background on the industry. Then, a theoretical model of the behavior of potential Indian software clients will be developed and applied to actual client behavior. Then, once we understand how the potential clients behave, I will theoretically model the Indian firm response and apply it to actual Indian firm behavior. Econometric techniques using actual data on over 190 software firms in the industry will then examine the magnitudes and interaction of the different factors developed in the models. The final section summarizes the findings and extends the implications of the model to other industries and developing countries. I then will suggest the public policy implications of the findings and speculate on the future of the industry.

**The Indian Software Industry Overview**

India has built itself on traditions of mathematics and science. Today, it has the world's largest technical workforce with over 3 million engineers, scientists, and other technologists and the second largest English speaking technical workforce. This large number of technical talent drives down the equilibrium wage in this sector. Less than three-fourths of this skilled workforce have technical or scientific jobs due to the lower wage and fixed number of jobs available (Zorpette 1994). This occurs because a technically trained person views this wage as the opportunity cost for going to work in another sector. A lower wage lowers this opportunity cost causing the skilled workforce to move into other sectors. With Indian programmers available for less than $12 to $15 per hour, Indian firms complete software projects for less than half the cost of in the
United States (Krepchin 1993). Therefore, by the theory of comparative advantage discussed above, the software industry should grow since foreigners see this lower wage as a free profit opportunity and exploit it. This creates a greater numbers of jobs in the industry and the skilled workforce reallocates itself back into this sector.

For 1994, the industry had sales of rupees 17.15 billion ($560 million) where ten years back it had less than rupees 300 million ($10 million), and it only employs around 120,000 people. The compound annual growth rate for the industry has been 38.6% with the export industry growing at 46.6%. The map in figure 1 shows the location of the major software activity. 61% of the exports are to the United States, 17% are to Europe, 5% are to West Asia, 4% are to Japan, and 5% are to Southeast Asia (Mehta 1995). This indicates that countries did exactly what the theory of comparative advantage predicts and took advantage of India's high endowment of skilled professionals.

The government set up several software technology parks in 1990 in locations shown in the map in figure 1. These parks make entry into the international software industry simple and only allow 100% export oriented units. Companies in these parks can import goods duty free and for the first five years without corporate taxes. The parks have centralized computing facilities and members get complete access to high speed data communication links and the internet. The leaders of the park provide the single governmental contact for all procedures such as licenses, import certificates, etc. allowing Indian firms to avoid the bureaucracy of the central government. In export processing zones, the government allows duty free imports, income tax holidays, and simplified procedures (The Indian Software Industry : Discover It). The units maintain themselves independently from the profits they earn from the companies that use them. According to N. Gopalaswami, the joint secretary of the Department of Electronics, five STPs make extremely high profits, four make slightly less, one is breaking even and two are struggling.
Figure 2 shows the types of activities in the industry. The activities allow foreign companies to utilize fully the skilled talent available to them in India. Large scale turnkey projects for sectors such as telecomm, gem exploration, and mining dominate the domestic software market while professional services top the export market. These professional services include customization of foreign packages and professional consultancy. Products and packages are not necessarily shrink wrapped packages but include general purpose products used for certain sectors (Mehta 1995). Much of the package work includes the creation of large scale vertical applications in areas such as
banking, manufacturing, insurance and other financial services (Malhotra Aug. 16-31 1995). Consultancy includes integrating information technology into companies and institutions. Within the top 72% of software activities, 60% are done on site while 38% are done offshore in India.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Domestic Software</th>
<th></th>
<th>Export Software</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rupees Million</td>
<td>% of total</td>
<td>Rupees Million</td>
<td>% of total</td>
</tr>
<tr>
<td>Turnkey</td>
<td>3096</td>
<td>45%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Professional Services</td>
<td>-</td>
<td>-</td>
<td>5040</td>
<td>50%</td>
</tr>
<tr>
<td>Products &amp; Packages</td>
<td>2416</td>
<td>35%</td>
<td>1030</td>
<td>10%</td>
</tr>
<tr>
<td>Consultancy</td>
<td>422</td>
<td>6%</td>
<td>2275</td>
<td>23%</td>
</tr>
<tr>
<td>Training</td>
<td>586</td>
<td>8%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Data Processing</td>
<td>320</td>
<td>4%</td>
<td>805</td>
<td>8%</td>
</tr>
<tr>
<td>Others</td>
<td>110</td>
<td>2%</td>
<td>870</td>
<td>9%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>6950</td>
<td>100%</td>
<td>10200</td>
<td>100%</td>
</tr>
</tbody>
</table>

Figure 2 : Activities of the Indian software industry

Source : Mehta 1995

Many companies also serve as domestic distributors or "agents" for foreign companies. Companies like Microsoft or Oracle use these companies as points of entry into the Indian software market. The distributors in India may further help integrate this foreign software into Indian systems. Therefore, Indian companies acquire much knowledge and quick profits by acting as these kinds of agents. Both lower end and higher end markets use professional and consultancy services. The international market requires the higher end work with the latest techniques and methodologies. Smaller companies usually dominate the lower end work that does not require the latest tools.

Besides purely Indian companies, many joint ventures exist as shown in figure 3. Joint ventures allow a transfer of methods and capital from one company to another. The western companies use their overseas partners as marketing channels and a source of skilled labor for their overseas operations. As shown in figure 4, large foreign companies also set up wholly owned subsidiaries in India for the same purpose. Large holding groups of companies that carry a well-known brand name also contain many of the software companies. For example, Tata Unisys and Tata Consultancy Services both associate with the well-known Tata group of companies.
330 companies currently work in the business of software exports. In 1993-94, 100 companies exported more than rupees 10 million in sales. This number was only 5 in 1991. In 1993-94, 15 companies exported more than rupees 150 million. Only 3 companies exported this amount in 1990. The top 20 Indian software exporters are shown in figure 5. The top 8 firms in the export market account for 35% of the industry revenues. The top 20 companies obtain 70% of the industry export revenue (Mehta 1995). The industry remains less competitive than comparable industries that require unskilled labor and many of the top companies gain significant profits. Therefore, some companies gain a large amount of market power while others do not. An interesting trend also seen in the industry is the move towards less market dominance by the top companies and a more competitive structure.
<table>
<thead>
<tr>
<th>Company</th>
<th>Exports (Rupees million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tata Consultancy Services</td>
<td>2000</td>
</tr>
<tr>
<td>Tata Unisys Ltd.</td>
<td>750</td>
</tr>
<tr>
<td>HCL Hewlett Packard Ltd.</td>
<td>405</td>
</tr>
<tr>
<td>Digital Equipment (India) Ltd.</td>
<td>384.1</td>
</tr>
<tr>
<td>ICIM Ltd.</td>
<td>322.5</td>
</tr>
<tr>
<td>Wipro Systems Ltd.</td>
<td>301.5</td>
</tr>
<tr>
<td>Silverline Industries Ltd.</td>
<td>300</td>
</tr>
<tr>
<td>Pentafor Software &amp; Exports Ltd.</td>
<td>283</td>
</tr>
<tr>
<td>Patni Computer Services</td>
<td>282.5</td>
</tr>
<tr>
<td>Infosys Technologies Ltd.</td>
<td>274.9</td>
</tr>
<tr>
<td>Citicorp Overseas Software</td>
<td>247.3</td>
</tr>
<tr>
<td>Information Management Resources</td>
<td>243.7</td>
</tr>
<tr>
<td>Siemens Information Systems Ltd.</td>
<td>199.6</td>
</tr>
<tr>
<td>Square-D Software Ltd.</td>
<td>194.3</td>
</tr>
<tr>
<td>Wipro Infotech Ltd.</td>
<td>155.3</td>
</tr>
<tr>
<td>Citicorp Information Technologies Industries Ltd.</td>
<td>144.6</td>
</tr>
<tr>
<td>Tata Information Systems Ltd.</td>
<td>140.9</td>
</tr>
<tr>
<td>Mahindra British Telecom Ltd.</td>
<td>138.6</td>
</tr>
<tr>
<td>Texas Instruments (I) Ltd.</td>
<td>138.4</td>
</tr>
<tr>
<td>PSI Data Systems Ltd.</td>
<td>137.3</td>
</tr>
</tbody>
</table>

Figure 5: The top 20 software exporters  Source: Mehta 1995

Models of Customer and Firm Behavior in the Indian Software Industry

In developing a method to understand how transaction costs due to asymmetric information effect the Indian software industry structure and evolution, I will examine the behavior and incentives of both parties in the transaction. First, I will examine the potential foreign customers of the industry and see how they make their decisions. Then, I will use this information to examine how Indian firms have behaved to become successful in satisfying these needs. Simple graphical models will provide a method to better understand the decisions made by both sides.

Behavior of Potential Indian Software Clients: A Theoretical Model

Companies looking for software services realize that India has a large number of technically talented people available at a lower cost. As mentioned in the introduction, companies wish to use this talent to undergo their software projects at a lower cost.
Western companies gain by the lower prices while technically talented people reallocate back into the sectors which suit their talents. This occurs because they receive higher wages due to the increase in demand for their services.

Potential clients, however, remain unclear on the abilities of the Indian talent to do credible, quality projects within a well-defined time frame. In other words, information asymmetry exists between the providers of the software services in India and the potential customers in western countries. They do not know whether the talent in India has the ability to provide the type of services or products in the manner and specifications that they need. This becomes especially crucial in large-scale software projects where the client's organization and profitability depends on the proper implementation and management of systems. At the initial growth of the industry, a viable domestic market did not even exist which further raised the concern of potential overseas clients. In light of these concerns, how do the foreign companies gain the information on companies in India and find one that may closely satisfy their needs and concerns?

They have to search for them. Although western companies know of the cheaper technical talent available to them overseas, they incur an additional search cost in looking for the firms that have the abilities to satisfy their specific needs. If this search cost is too high, clients may not find using the Indian talent feasible and a mutually beneficial transaction will fail to occur. The transaction becomes profitable only if the benefit of using the Indian talent outweighs the cost of searching.

Now let's try to model how the western firms behave when trying to select an Indian company. This model will include ideas of traditional comparative advantage models with the new concept of transaction costs involved in searching for the right Indian company. Consider a western firm searching for an Indian partner to complete a software project. Subtracting the cost of using an Indian company from the benefit gives the gain that the western firms obtain from using an Indian company
\[ G_{w,I} = B_{w,I} - C_{w,I} \]  

where \( G_{w,I} \) = Gain to the western company in using Indian firm  
\( B_{w,I} \) = Benefit to the western company in using Indian firm  
\( C_{w,I} \) = Cost to the western company in using Indian firm

Now, what is the benefit of using an Indian company? As mentioned at the beginning of the paper using traditional comparative advantage models, companies use Indian firms if the cost of a software project is cheaper in India then in the local domestic country as shown in equation (2).

\[ B_{w,I} = C_{p,w} - C_{p,I}(s) \]  

where \( \frac{d(C_{p,I})}{ds} < 0 \)  
\( C_{p,I}(s) < C_{p,w} \)  
\( C_{p,w} \) = Cost of a software project done by western firms  
\( C_{p,I}(s) \) = Cost of a software project done by Indian firm  
\( s \) = Search effort by western firms to attain required quality

The cost of doing a project in India is a function of the search effort because the client searches for the lowest cost company and the more effort the client spends the lower project cost company he or she is likely to find. Therefore, \( C_{p,I}(s) \) is a decreasing function of \( s \).

Now what is the cost, \( C_{w,I} \), of using an Indian company? As mentioned earlier, the western firm must spend effort searching for the right Indian firm that satisfies its needs and this effort incurs a search cost. Therefore,

\[ C_{w,I} = SC(s) \]  

where \( \frac{d[SC(s)]}{ds} > 0 \)  
\( SC = \) search cost

The search cost is an increasing function of search effort so that as a firm spends more effort searching, the search cost increases. Now plugging this into the equation (1).

\[ G_{w,I} = (C_{p,w} - C_{p,I}(s)) - SC(s) \]  

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Now, this function is maximized by taking the derivative of the above expression with respect to search effort and setting this derivative equal to zero.

\[
\frac{d}{ds} \left[ (C_p - C_p(s)) - SC(s) \right] = 0
\]  

(5)

We get the following equation that maximizes the gain

\[
\frac{d(C_p, I(s))}{ds} = -\frac{d(SC(s))}{ds}
\]  

(6)

To ensure the existence of a maximum, we must assume

\[
\frac{d^2(C_p, I(s))}{ds^2} < -\frac{d^2(SC(s))}{ds^2}
\]

Intuitively, this equation maximizes the gain of clients and indicates that they will continue to use effort in searching for a quality company until the search cost of spending the next marginal unit of effort equals the reduction in the cost of a project in India obtained from using the next marginal unit of effort. This equilibrium level of search effort will be denoted as \( s^* \). Beyond \( s^* \), potential clients will no longer find it beneficial to devote these resources because the search cost of the next level of effort is greater than the cost reduction of spending effort finding the next, lower cost firm. Therefore, they will chose the Indian company which best fits their needs within this search period. This model provides a way of understanding how much effort the western client will spend in searching for an Indian company. However, it does not assume that the client will pick the last, lowest cost firm. The client will chose from the firms that it encountered in the equilibrium level of search effort that also best fits its needs and provides the highest quality work. If it fails to find an Indian firm with the proper mix of skills within this search effort, it will go back to using its local, western companies. Some firms may even find searching for an Indian company economically unfeasible. This result where the equilibrium level of search, \( s^* \), equals zero is called a corner solution. This occurs when

\[
\frac{d(G_w, I(s))}{ds} < 0
\]
Now that we understand this theoretical model of how potential clients behave, we can confirm this by looking at how actual clients in the Indian software industry make decisions.

**Actual Behavior of Potential Indian Software Clients**

A 1992 World Bank funded study surveyed potential western clients on the criteria they use in choosing software companies. Since the World Bank conducted the survey in 1992, some issues such as communication infrastructure or security may not be as relevant today. However, this study does help us to understand exactly the type of asymmetric information that exists in using Indian companies.

The survey asked different groups of people to rate a set of decision criteria from 1 to 5 (5 being highest). Figures 6-8 show the vendor rating when selecting software subcontractors in their domestic market, the foreign market, and Indian market.

![Vendor criteria for selecting local, domestic software contractors](image)

Source: Maxi/Micro Inc., International Data Corporation and IDC (India) 1992
The survey results show some strong conclusions. When selecting foreign or Indian subcontractors, vendors rated cost as the second most important criteria, while for the domestic subcontractors cost was not a major issue relative to other concerns. This provides evidence for the move towards Indian software companies because of the cost difference as shown in the previous model. As well, quality ranks most important in all three segments. Asymmetric information arises because vendors have more knowledge of the quality of their domestic companies than they do of the foreign companies. Therefore, they have to search for information on the quality of Indian companies.
A similar survey was done for users. Figures 9-11 show the results for the user survey.

A similar result appears for users with quality and cost as their top criteria. Again, when western users want to use foreign and specifically Indian talent, cost is a larger factor then when using domestic companies. We can also see that potential foreign users require information on the quality, project management skills, and technical competence of the Indian software companies.
A survey of vendors not doing business in India shows this asymmetric information in a stronger way. In this survey, the vendors gave a rating of what their requirements were in using Indian software talent and what their current perceptions were. The difference between the two ratings will be called the "GAP".

\[
\text{GAP} = (\text{rating from 1-5 of what users or vendors require when using Indian firms}) - (\text{rating from 1-5 of users or vendors perceive when using Indian firms})
\]

The results are shown in figure 12. The notable large GAPs occur in the ease of doing business, post implementation support, project management, and quality. The communication infrastructure and security are no longer significant issues in the Indian industry due to the rise of software technology parks and stronger piracy regulations.

Now we can see exactly why foreign vendors do not use Indian companies. We see this by looking at the results of the surveys of users and vendors in figures 12 and 13 who chose not to do business with Indian firms but rather use the local companies. For both figures, project management, quality, ease of business, and technical competence all have a GAP of greater than 1.
These differences in requirements and perceptions reflect the lack of complete information that vendors have in using Indian talent. They also reflect the high search efforts that the vendors must spend in finding companies which fulfill their requirements. Putting this in the framework of the model developed earlier, these companies may not have been able to find the right Indian company to satisfy their needs within the equilibrium search effort, $s^*$, that they spent in trying to find them. Therefore, a GAP existed between their requirements and their perceptions from the search efforts that they have done and they moved back to their domestic companies.
Now that we understand the behavior of potential clients on both a theoretical and practical level, we can turn towards the behavior of Indian firms in response to this. Again, I will examine this response on both a theoretical level and then a more practical one.

**Behavior of Indian Firms : A Theoretical Model**

Understanding this model of how potential clients behave can help explain the incentives for Indian companies. Successful Indian companies must increase the chance that the searching client finds their company and selects it. Increasing the chance of being "found", means that a western company must find the Indian client within an s* amount of search effort. If not, the client will never find the Indian company because he or she will not find it economically feasible to devote any more effort beyond s*.

Therefore, the Indian company has the incentive to lower the amount of effort that a western client must devote to searching for it. However, for an Indian company to do this, it must devote its own resources to increasing its awareness in the market and must also convince the western company of its abilities once it is found. Therefore an Indian company would like to:

1) Make it possible for the foreign company to find them at the minimal amount of search effort.
2) Signal and convince the foreign companies of their abilities once the company finds them.

The effectiveness of these signals depends on if the foreign companies can use them to separate high quality and highly skilled companies that match their needs from ones that do not. This separation occurs because less qualified companies do not find it economically feasible to use the signals while qualified companies do. High quality firms that signal their abilities to foreign companies will tend to grow since they can effectively show their potential clients that they have the ability to do good work.

To better understand this behavior, we can graphically model the reaction of the Indian companies given the behavior of the potential foreign customers developed earlier.
In other words, we can see how companies can optimally react to the earlier model on the behavior of potential foreign customers.

Pindyck and Rubinfield's (1989) model on job market signaling provides a simple basis for examining the reaction of Indian companies. In the job market model, employers do not have total information on the people they interview for jobs. However, people within the job market can signal their abilities by going to college. Since only the top quality people will find it worth the cost to go to college, it provides an effective signal of abilities. By signaling their abilities, people reduce the amount of search effort that an employer must spend in finding the right person for the job. This occurs because their abilities are summed up in a single, measurable, and simple factor, college education. Employers know that the years of college education can effectively separate out productive people from nonproductive ones and, therefore, rely on it as an effective signal.

In a similar manner, Indian companies must provide useful and credible signals of their abilities. These signals must reduce the search effort of the foreign companies in a similar simple manner and clients should be able to rely on them as effective measures of a firm’s quality. Later in the paper, I will discuss the actual signals used by Indian software companies and examine the effectiveness of these signals in my empirical work using firm level data. Right now, I will motivate this behavior with a graphical model. I will use equation (1) but from the standpoint of the Indian firm as shown in equation (7).

\[ G_{I,w} = B_{I,w} - C_{I,w} \]  

(7)

where

- \( G_{I,w} \) = Gain to the Indian firm in getting western client
- \( B_{I,w} \) = Benefit to the Indian firm in getting western client
- \( C_{I,w} \) = Cost to the Indian firm in getting western client

Now the benefit is the revenue received for undergoing a project with the western client.

\[ B_{I,w} = R_{I,w} \]  

(8)

where \( R_{I,w} \) = Revenue received by Indian firm from western client
Now recall that an Indian company must signal its abilities because of the asymmetric information that exists between the western clients and the Indian company. Examining both the cost and revenue side of equation (7) will help us to find the equilibrium level of signaling.

Suppose that we represent the amount of a particular observable signal that an Indian company could use as $y$. Therefore in equation (7) the cost of obtaining a western company is a function of a particular signal that an Indian company must do. If we partition the Indian companies into two groups, we can better evaluate this cost. Group I contains poor companies which do not satisfy the needs of the foreign companies well while group II contains highly skilled companies that do. An important thing to remember in developing this model is that membership in Group I or Group II is exogenous to the model meaning that companies can not switch from one group to another. Group I faces a higher cost in devoting resources to a particular observable signal. Companies in group I will not have the quality of resources to signal their abilities as would a group II company. For example, some quality companies signal their abilities by collaborating with a foreign company. Potential western clients hope that the partner provides the skills and methodologies to make the company a credible one. Poorer companies may find it more difficult to find a collaboration or may not find one at all since the collaborator will only become a partner if it is profitable to do so. Poorer companies also have a lower probability of being chosen and, therefore, may have to devote more resources than necessary to "fool" the customer with false signals. As well, they incur an addition cost due to the risk of entering the market with less of a quality company since they may not be chosen even if they are found. Realizing this, we can now examine the cost side of equation (7) for both types of firms. For group I people, the cost of devoting more resources to signal, $y$, is
and for Group II

\[ C_{I,w}^{II}(y) = by \]  \hspace{1cm} (10)

\[ a = \text{constant} \]
\[ b = \text{constant} \]
\[ a > b \]

We can now look at the revenue side of equation (8). A western company must rely on certain signals before it will choose an Indian firm that satisfies its needs. The signal must be simple such as years of college in job market signaling, and must effectively separate the poor firms from the quality ones. Now let’s assume that western companies find that after a level of signal \( y_1 \), they can be relatively certain that they have found a good quality company that satisfies their needs. Therefore, they decide to use the Indian company that effectively provides this level of signal and the company gains the level of revenue \( r^* \). Remember that the western firm selects companies that it finds with this level of signaling within the equilibrium search effort, \( s^* \). This increase in earnings is the benefit of signaling and is shown in equation (11).

\[ B_{w,J} = R_{I,w}(y) = \begin{cases} 
0 & y < y_1 \\
r^* & y \geq y_1 
\end{cases} \]  \hspace{1cm} (11)

Plugging equations (9), (10), and (11) into equation (7) we get for group I.

\[ G_{I,w} = R_{I,w} - ay \]  \hspace{1cm} (12)

and for group II

\[ G_{I,w} = R_{I,w} - by \]  \hspace{1cm} (13)

where \( R_{I,w}(y) = \text{equation (11)} \)

Both group I firms and group II firms wish to maximize equations (12) and (13) respectively. Although we can do this by taking the derivative of the equations with respect to \( y \) and setting it equal to zero, it may be easier to see the solution graphically as in figure 14 due to the step nature of the benefit function.
Figure 14: Optimal level of signal, $y_1$

Looking at figure 14, we maximize gain for group II firms at $y_1$ since the difference between the benefit and cost is greatest at this level of signaling. Group I firms suffer negative gains at all signaling levels so they do not find it feasible to signal. Therefore, this signal effectively separates poor firms from quality ones and the western company has selected the appropriate signal to find the right firm. If signaling is relatively less costly, both types of firms will find it feasible to signal at $y_1$ making the signal ineffective in separating high quality firms from poorer quality ones as shown in figure 15.

We can now turn towards how the actual firms in the Indian software industry follow the models developed in this section. The rest of this paper will be practical in nature but will always refer back to our theoretical understanding developed so far. I will first examine how firms in the Indian software industry successfully signal their abilities such that the client finds and selects the firm within $s^*$ level of effort. Then, empirical analysis on over 190 firms will help determine the relative impact and relationship of these different signals and how they effect firm growth.
How Indian Firms Lower Client's Search Effort by Signaling

Indian software firms must devote their own resources to signaling their abilities so that the potential western client finds them within the equilibrium level of search effort. A firm could easily do this by providing homogeneous products or, in other words, providing the same good or service repeatedly. If a firm can show that it has undergone the same type of consultancy work or project many times before, potential clients may not doubt their ability to do it again. In fact, early in their development many successful companies became identified with one or two particular areas and then expanded into other areas as they grew. Wipro Systems specialized in systems work for the communication sector and became experts in UNIX. The company quickly became identified with these two areas and grew rapidly. The idea of product homogeneity even further explains the rise in software products and package exports. Firms implement and slightly customize the same products for the same type of application repeatedly. Once the company has implemented the packages many times before, it has no problem convincing a potential customer that it can do it again. Manhattan Associates in Bangalore has an installed base
of over 140 customers in the United States for its distribution, retailing, and warehouse management software.

Relationships with leading foreign companies provide a powerful signal of the abilities of Indian companies. This occurs because the international company will have a known name that the potential overseas clients recognize. Figure 16 shows these types of relationships.

<table>
<thead>
<tr>
<th>Type of Relationship with Foreign Company</th>
<th>Amount of Ownership by Foreign Partner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subsidiary</td>
<td>full</td>
</tr>
<tr>
<td>Joint Venture</td>
<td>partial</td>
</tr>
<tr>
<td>Agency Operations</td>
<td>none</td>
</tr>
</tbody>
</table>

Figure 16: Types of international relationships

Aligning with a western company in a joint venture allows Indian companies to signal that they have gained knowledge from their partner. Overseas companies become comfortable in dealing with these Indian firms since they often recognize the partner's name and abilities as shown in figure 3. Members of the Indian software industry find joint ventures advantageous since they both allow them to acquire the knowledge of their partner and signal their abilities easily to an overseas client. Overseas companies have the incentive to undergo these joint ventures with Indian firms since they may find that their market share may be declining in their high priced services, and profits are increasing with the Indian companies. In addition, the Indian companies often end up doing much of the work for their overseas partner. Therefore, it gives the foreign software companies an opportunity to take advantage of the cheaper labor costs in India in the same manner that the potential western companies do. They benefit from both sides of the transaction since they act as the software service provider and the customer.

Vijay Thadani, CEO of NIIT, noted that the company relied heavily on collaborations for gaining knowledge and signaling their abilities in the marketplace. Currently partnered with over 24 overseas companies, the company grew from its inception in 1981 to an over rupees 123 crore company today. Increasing collaborations
was the primary focus of NIIT early in its growth. They used a specific model of interaction with their collaborations where both sides benefited by learning from their alliance, refining their methodologies, mastering them, and giving back to partners through software work and training.

When clients need a large amount of important systems work on a continual basis (like a worldwide bank), they may devote extensive resources to finding the right Indian company and may still not find one within $s^*$. However, they find ways to exploit this cost difference by setting up branches in India known as "wholly owned" subsidiaries. By setting up a subsidiary, western firms reduce the asymmetric information costs because they have complete control over the running of the organization. Many of these wholly owned subsidiaries exist in India where the Indian branch does work solely for the parent company. Figure 4 shows some examples of these organizations. The empirical work of Ramachandran (1993) found that subsidiaries of companies in India do indeed receive the greatest amount of resources over any other type of ownership. This provides evidence that these foreign companies try to maintain control over these subsidiaries to undergo projects using their standards and methodologies.

Joint ventures and wholly owned subsidiaries show a type of signaling where well-known companies have some type of ownership of the Indian technical talent. However, another type of international relationship arises where foreign companies have no ownership. This occurs when Indian companies do agency operations. Agency operations are when an Indian firm becomes a distributor of a well-known, overseas software company such as Oracle or Microsoft. They may even undergo projects that involve implementing the western software that they distribute. The foreign companies often train the Indian firms on the products as well as the methods of implementation allowing them to quickly acquire knowledge from the foreign companies and apply it to other types of work. Potential customers in foreign countries recognize this and feel more confident in using these companies especially if the companies have successfully
implemented the software in the domestic market before. As well, knowledge of particular products makes it easier for the foreign client to see exactly the type of skills that the company has acquired. Therefore, the client can more readily evaluate if the Indian company's skills match their needs.

So far, we have seen how international relationships may provide a means to signal to overseas companies. However, some Indian companies have relationships with larger, more well-known Indian companies such as a widely recognized Indian holding group. However, this signal may not be as strong since the foreign client will not have as much knowledge about them as an international partner. Therefore, to evaluate the effectiveness of these signals, we must turn to empirical data to see whether foreign companies see these as credible signals and have knowledge of the Indian partner. Many companies remain part of these larger groups and execute software projects for other members of the holding group. They use this to show that they have done successful projects and have acquired skills help them venture into other markets. Many software companies also arise as offshoots of hardware companies that need software implementation along with their hardware work. These companies effectively "piggyback" off hardware sales and gain considerable expertise that can signal their abilities to overseas customers.

The creation of overseas branches provides one of the most effective ways that Indian companies have to decrease the amount of resources that foreign companies have to spend in searching. By developing branches in every region they target, companies market directly to the companies and provide a local point of contact to the foreign company. As well, foreign companies can easily find information about the company through local branches and can receive local support for the work that the Indian companies do. Marketing through these offices must be specific and aggressive. Many less successful companies rely too much on "word of mouth" marketing or previous contacts. However, the simple development of branches does not ensure the abilities of
the companies unless it has already established some type of reputation or signals its abilities to the overseas customer through methods previously described. Branches simply provide a vehicle for the flow of information from India to the overseas customers.

**Current Industry Structure**

How does this theory explain the current structure of the Indian software industry? The top 8 firms in the export market account for 35% of the industry revenues. The top 20 companies obtain 70% of the industry export revenue. The remaining hundreds of small to midsize companies obtain only 30% of the total revenue (Mehta 1995). The larger companies do higher end customization and reengineering using the most current techniques, methodologies, and technologies mostly for the international market while the smaller companies tend to do lower end customization and reengineering that require simple computerization and information technology needs. Companies generally gain market share in the industry by effectively signaling their abilities to the overseas customer and convincing the potential client of their abilities.

The largest companies were often the first ones to start international work early in the growth of the industry. They were "pioneering brands" as noted by Schmalensee (1982) where they establish themselves early as quality companies with a reputation for good work. Schmalensee showed that through this method companies can differentiate themselves in a manner different from simply advertising. In Schmalensee's model, companies enter sequentially into the market and the potential customers feel initially unsure about the quality of the firm's work. When the overseas client become convinced that these first companies can execute the work by seeing them do it successfully, they use them as a benchmark to rationally judge subsequent entrants. This gives later entrants a disadvantage because the overseas customer must invest search effort in learning about the new company's quality and abilities while they already know about the established incumbent in the industry. In this framework, the later Indian software companies will not try to totally emulate the current pioneering companies. Rather, they will differentiate
themselves from the current leaders so a sizable amount of foreign companies find them pioneering and not following. Therefore, to penetrate the market, new entrants must do either one of two things. They can either provide a higher quality product or lower the resources that the foreign companies spend on learning about quality through signaling. As noted by B V Vankatesh, Executive Director of the three year old BFL software, the biggest competition in the international market is not multinationals, but homegrown companies like Tata Consultancy Services, Wipro, and Infosys since they have established themselves well in the market.

The concentration of the industry provides evidence that significant entry barriers exist in international work. The top ten companies work in an oligopoly structure where significant barriers come from either being pioneering firms or having already signaled to the bulk of the potential overseas market. However, the hundreds of smaller companies work in more of a competitive nature with easy entry and exit and lower prices. The larger companies have made large investments to disseminate information about themselves and to signal new clients. This includes the formation of branches and numerous joint ventures, large training facilities, and constant knowledge of the latest technology. For example, figure 17 shows some statistics for the largest and oldest companies in the Indian software business.

<table>
<thead>
<tr>
<th>Company</th>
<th>1995 Software Revenue (Rs. Crore)</th>
<th>Number of Employees</th>
<th>Years Open</th>
<th>Number of collaborations</th>
<th>Number of agency operations</th>
<th>Number of branches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tata Consultancy Services</td>
<td>35228</td>
<td>4400</td>
<td>27</td>
<td>0</td>
<td>6</td>
<td>43</td>
</tr>
<tr>
<td>Tata Unisys Limited</td>
<td>10846</td>
<td>1598</td>
<td>17</td>
<td>3</td>
<td>6</td>
<td>30</td>
</tr>
<tr>
<td>Wipro Infotech</td>
<td>9393.92</td>
<td>1789</td>
<td>14</td>
<td>2</td>
<td>0</td>
<td>28</td>
</tr>
</tbody>
</table>

Figure 17: Signaling by "pioneering" firms. Source: Malhotra Aug 1-15, 1995

Companies in the more competitive sector do have an incentive to invest in providing information to the customer since it allows them to gain market power despite this relatively competitive structure. Investing in methods to disseminate information
makes it more difficult for later companies to gain power. Therefore, they can keep these rents and prevent competitors from accessing them. When a firm invests in market signaling, clients can either use the firm in which they already have knowledge or invest in finding information about an unknown firm. Customers usually find it profitable to stay with the known firm.

Companies may not find other types of investment as profitable such as investment in technology or new methodologies. Once a firm in the competitive sector starts using a new technology, all the firms start using it causing the competing away of potential profits. Therefore, companies wishing to transition away from this competitive sector have incentive to invest in methods that signal their quality methodologies and their abilities to overseas clients rather than in methods that simply advance their techniques. However, they must invest in new technology to at minimum keep up with the competitive nature of the industry.

In order to improve information dissemination and gain market power, firms may require large investments. Rationally, this should not be a problem since it is an immediate profit opportunity. Venture capital companies "search the streets" of cities like Bangalore and Bombay to find unknown companies that have the potential to grow and many companies make money through agency operations and collaborations. These all provide signals of quality and sources of capital for investment. In addition, many spin-offs of larger holding companies and engineering firms have gained investment capital through these associations.

**Empirical Examination of Indian Software Firms**

Examining data on actual firms in the industry and modeling their behavior can provide a quantifiable means for understanding how different aspects of the theory in the earlier section impact firm behavior. As mentioned before, firms must spend a certain amount of search effort in trying to find an Indian company that does quality work and can satisfy their needs. They find it feasible to do this only until the marginal search cost
equals the decrease in the project cost from searching. If a company does not find the proper Indian firm within the equilibrium level of searching, it will use domestic software firms. Therefore, a quality Indian firm has the incentive to signal its abilities to the western firms so that the firm finds them within the equilibrium search effort, $s^*$. Indian firms signal at a level where the revenue received from signaling exceeds the signaling cost as much as possible.

When companies select signaling levels that do this, they grow since their revenues exceed their costs and they gain profits. Recall that western companies rely on these signals because only higher quality firms will find it beneficial to use them as shown in figure 14. This section examines different signaling devices that Indian firms have used and their contributions to the firm growth in this manner. If both poor and high quality companies find it economically feasible to use a particular signal, the western company will not use it and the signal will not contribute to Indian firm growth.

Keeping this theory in mind, I will develop an empirical model and apply it to over 190 firms in the industry to evaluate the magnitude of the impact of these signals on firm growth rates. This way, we can evaluate which signals western firms rely on and which ones are not as effective. In this section, I will first discuss the nature and source of my data set. Then, I will discuss the variables that I examine in my model. Finally, the empirical model and its results and implications will be presented.

**The Data**

One of the largest Indian computing publications, *Dataquest* published by Cybermedia (India) Ltd. (not to be confused with Dataquest Inc., a company of Dun & Bradstreet, USA) prints a special, annual two volume issue that provides comprehensive analysis and data on the Indian software industry. This paper uses annual firm data compiled for the years 1991-1995 by *Dataquest*. The data set includes an analysis of 193 firms over this period. The composition of the firms in the set is shown in figure 18.
<table>
<thead>
<tr>
<th>Subcategory</th>
<th># of firms</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age of Company</strong></td>
<td></td>
</tr>
<tr>
<td>&lt;10 Years Old</td>
<td>148</td>
</tr>
<tr>
<td>&gt;10 Years Old</td>
<td>45</td>
</tr>
<tr>
<td><strong>Size of Company</strong></td>
<td></td>
</tr>
<tr>
<td>&lt;100 Employees</td>
<td>154</td>
</tr>
<tr>
<td>&gt;100 Employees</td>
<td>39</td>
</tr>
<tr>
<td><strong>Markets</strong></td>
<td></td>
</tr>
<tr>
<td>International or International + Domestic</td>
<td>94</td>
</tr>
<tr>
<td>Domestic Only</td>
<td>99</td>
</tr>
</tbody>
</table>

Figure 18: Characteristics of firms in the data set

**Description of Variables**

This section describes the variables on the Indian firms that were analyzed in the empirical model.

**Dependent Variable**

**GROWTH**

This variable represents the continuously compounded one-year growth rate in firm revenue from $t_0$ to $t_1$ where $t_0$ represents the base year and $t_1$ represents the following year. The growth rate is calculated by the equation

$$GROWTH = \ln \left( \frac{\text{Revenue} \left( t_1 \right)}{\text{Revenue} \left( t_0 \right)} \right)$$

(14)

The entire data set consists of the one year transitions in revenue growth from 1991-92, 1992-93, 1993-94, and 1994-95 for the selected firms. In other words, each firm could have up to 4 observations in the data set representing each of the one-year transitions in revenue over the specified time period.

**Independent Variables**

The independent variables were taken in the base year of the one year transition in revenue growth. Therefore, the model examines how initial conditions effect the one year growth rates for each of the years examined.

**YEARS**

This variable represents the number of years that the firm has been in business from its startup to 1995.
INTER
INTER is the percentage of the firm’s revenue that is obtained through international work.

EMPLOY
EMPLOY represents the number of employees in the company.

BRANCH
This represents the number of branches that the firm has either overseas or domestically.

SQBRANCH
This is the square of the BRANCH variable.

COLLAB
The COLLAB variable represents the number of overseas collaborations that the company has.

SQCOLL
This is the square of the COLLAB variable.

GROUP
GROUP is a dummy variable that is "1" when the firm is a member of a well-known domestic holding company or set of companies and "0" otherwise. For example, the most popular group of companies, Tata, contains Tata Unisys and Tata Consultancy services. Each of these companies would have a dummy variable of “1”.

HWGROUP
This is another dummy variable which takes the value of "1" if the company mainly does work in hardware but has a software portion and "0" otherwise.

AGENCY
A company that has agency operations provides domestic distribution and service of overseas products for well-known companies such as Oracle or Microsoft. This variable represents the number of overseas companies that the Indian firm is an agent for.
The Model

The goal of developing this model is to show how well the industry actually follows the theory previously discussed. Recall that foreign companies wish to take advantage of the less expensive engineering talent available in India but have to spend resources to search for the right company to satisfy their needs. This occurs because of transaction costs due to asymmetric information existing in the market where the foreign clients may not have knowledge of which companies to use and which ones can do quality work. Good Indian companies, therefore, have the incentive to lower the search cost for the foreign client so that the client "finds" them. This accounts for the imperfectly competitive nature of the Indian software industry where some companies who can effectively signal their abilities to the foreign companies grow and gain market power while others do not. In this section, I will develop a model to show the impact and interplay of these different signals and how they account for their growth. Often, the simplest models can provide the most powerful and intuitive results and this is the type of model I will develop here.

An important thing to remember is that the dependent variable, GROWTH, represents the one year growth rate. Therefore this empirical model looks at how these different methods of lowering the potential client's search costs by signaling effect its growth rate. A rate accounts for the size effects that occur when using revenue levels. In general, a company’s growth rate will tend to slow down as it becomes larger. This occurs because the older company has fully signaled to a large portion of their potential clients and thus experience lower growth rates. I attempted to take these types of effects into account in the model.

Before examining the signals directly, I first attempted to see whether the number of years that a firm has been in the industry increases the growth rate. In other words, do the potential clients chose the Indian firm based on the length of time they have been in the business or size. Therefore, the YEARS variable was included in the model.
The model presented earlier shows that only good, quality firms will have incentive to devote resources to signaling to the potential customer. Therefore, we can see if the amount of international work has an effect on the growth rate. Since only good, quality companies find it worthwhile to signal, companies that obtain a larger portion of their revenue through international work may tend to grow faster by taking advantage of the rapidly growing international market.

Branches located near target customers provide an effective way to lower search costs for the client. They also provide a simple way to disseminate information on the company's abilities and methodologies. However, one would expect that branches may have a different effect on growth rates when the Indian firm creates the first branch versus the thirtieth branch. When they develop the first branch, they signal to a large, new market. However, as time progresses and the company gains a reputation, the branches will have less of an effect in growth. Therefore, the model contains the branch variable in a nonlinear way by having a branch and \((\text{branch})^2\) specification.

A similar theory applies for the collaboration variable. The effect of the first collaboration may differ from that of later collaborations. Therefore, the model also contains this variable in a nonlinear manner. Recall that a collaboration with an overseas customer provides a powerful signal to the potential overseas client. It shows that the Indian company has learned the methodologies and techniques from the overseas partner. Therefore, the potential client may feel more comfortable using a company with an overseas collaboration.

Agency operations where an Indian company distributes a foreign product domestically also provides a signal to the potential overseas client. Often, the Indian company must modify the product for different types of domestic customers and must receive direct training from the foreign company to do this. Therefore, when the Indian company moves into the international market, its potential client may feel more confident of its abilities since it has had direct knowledge of the product. The strength of the signal
comes from the knowledge that the foreign client has on exactly the type of skills that the company has acquired since the products that the Indian firm sells domestically are often popular worldwide. Therefore, we would expect a different effect than collaborations and branches with the agency variable. As the company starts selling more products domestically, it shows that it has acquired more directly measurable skills on more products causing the effect on growth to be similar for the first agency operation as the third. Therefore, the model contains the agency variable linearly.

The final empirical model is specified in the following manner:

\[
GROWTH = \alpha + \beta_1 YEARS + \beta_2 INTER + \beta_3 EMPLOY + \beta_4 BRANCH + \beta_5 SQBRANCH + \beta_6 COLLAB + \beta_7 SQCOLLAB + \beta_8 GROUP + \beta_9 HWGROUP + \beta_{10} AGENCY + \epsilon
\]

(15)

**Results**

The regression results are shown in figure 19. In general, the results confirm the importance of signaling to lower the effort that the client must spend in searching for the Indian company and shows how these signaling techniques cause some companies to grow and gain market share while others do not. We can also now understand the magnitude of the impact of each of these variables on a company’s ability to grow.

Specifically, the YEARS variable appears to be estimated precisely and is negative. This confirms two aspects of the theory described earlier concerning the two types of firms:

1) Lower quality firms (Group I firms described above) do not find it worthwhile to signal in the international market or try to signal but do not do so effectively. They suffer in growth over time and fail to gain market share in the industry. This is described in the theory based on the Pindyck and Rubinfield (1989) model on labor market signaling.

2) Firms who have grown to a significant level have fully signaled to a large bulk of the potential international market and tend to have slower rates of growth over time and sometimes suffer negative growth. These include the "pioneering" firms described by
Schmalensee that entered the industry early on and have already established a reputation for good work. These will tend to grow at slower rates as they spend more years in the industry. The effect of number 2 above is further confirmed by the EMPLOY variable which shows that the size of the company essentially has no effect on its growth rate.

The precision of the BRANCH variable indicates that companies tend to grow when they create more overseas branches because they signal their abilities easily by branching in the markets that they directly target. Notice that the square term is slightly negative indicating that after a certain point, the effect of branches tapers off. This usually occurs with "pioneering" firms that have become large and have already signaled to a bulk of their potential market. For this particular model this effect occurs at about 38 branches which is very close to the number of branches established by the largest and oldest firms in the business as shown in figure 17.

The SQCOLLAB variable also appears to have a nonlinear relationship with the growth rate. Although the level of COLLAB has no effect, the SQCOLLAB shows that collaborations have an increasing effect on growth rate. In other words, the first collaboration increases the growth rate differently then the fourth or fifth. This makes sense within theory since collaborations provide powerful signals that the company has learned the software development methodologies from their overseas partner. However, this indicator does not take into account the type of company that the Indian firm has collaborated with but only looks at the number of collaborations. A collaboration with a larger, well-known company may have more of an effect than a smaller overseas partner. This may account for the lower level of precision of the t-stat in the regression. An investigation of the linear COLLAB variable provided no precise or meaningful results.

In a similar manner, the AGENCY variable shows that distributing a foreign product provides a signal of the abilities of the company. However, again, this indicator only takes into account the number of companies that the Indian firm distributes for not the type of company. This may account for the lower level of precision of this variable as
well. For both the SQCOLLAB and the AGENCY variables, a general conclusion can be made that the increase in these relationships with foreign companies provides a good signal of abilities and increases a company's growth rate.

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>GROWTH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>0.45065</td>
</tr>
<tr>
<td></td>
<td>(6.48899)</td>
</tr>
<tr>
<td>YEARS</td>
<td>-0.013083</td>
</tr>
<tr>
<td></td>
<td>(-2.40507)</td>
</tr>
<tr>
<td>INTER</td>
<td>0.012447</td>
</tr>
<tr>
<td></td>
<td>(2.63897)</td>
</tr>
<tr>
<td>EMPLOY</td>
<td>-3.44E-05</td>
</tr>
<tr>
<td></td>
<td>(-0.464344)</td>
</tr>
<tr>
<td>BRANCH</td>
<td>0.031265</td>
</tr>
<tr>
<td></td>
<td>(2.62923)</td>
</tr>
<tr>
<td>SQBRANCH</td>
<td>-4.01E-04</td>
</tr>
<tr>
<td></td>
<td>(-2.91764)</td>
</tr>
<tr>
<td>COLLAB</td>
<td>-0.066882</td>
</tr>
<tr>
<td></td>
<td>(-0.649062)</td>
</tr>
<tr>
<td>SQCOLLAB</td>
<td>0.028157</td>
</tr>
<tr>
<td></td>
<td>(1.22002)</td>
</tr>
<tr>
<td>GROUP</td>
<td>-0.124923</td>
</tr>
<tr>
<td></td>
<td>(-1.35754)</td>
</tr>
<tr>
<td>HWGROUP</td>
<td>-0.170359</td>
</tr>
<tr>
<td></td>
<td>(-1.77964)</td>
</tr>
<tr>
<td>AGENCY</td>
<td>0.027041</td>
</tr>
<tr>
<td></td>
<td>(1.26799)</td>
</tr>
<tr>
<td>No. of observations</td>
<td>358</td>
</tr>
<tr>
<td>R²</td>
<td>.044</td>
</tr>
</tbody>
</table>

(t-stats are indicated in parenthesis under the coefficients)

Figure 19: Estimation of empirical model parameters

The effect of a firm having a relationship with other, more well-known, Indian companies rather than an international one provides an interesting result in this model. The variables up until now such as COLLAB, SQCOLLAB, and AGENCY reflect relationships with overseas, western companies. However, the GROUP and the
HWGROUP dummy variables show software companies with relationships with other Indian companies. These relationships tend to have a negative to no effect on the growth of Indian software firms making these ineffective signals to obtain potential overseas or domestic clients. Let’s look at this from the framework that was developed earlier. A potential overseas client has to spend resources in searching for an Indian company. Signaling aims to lower the amount of resources that the foreign company has to spend in finding an Indian company that suits its needs. Recall that an effective signal must be simple to do and a useful indicator of abilities such as the number of years of college education in the market for jobs. If an Indian company has a relationship with a foreign company that is well-known around the world such as Microsoft or Silicon Graphics, a potential client has immediate knowledge of their abilities and skills. However, if an Indian company has a relationship with another Indian company, the potential western client still may not have knowledge of their abilities since they may not know what the collaboration does or how good the collaborator is. In order to find this out, the client must search even more which incurs additional cost and takes away the simplicity and effectiveness of the signal.

As well, these signals may not be effective in separating poorer Indian firms from high quality ones as shown in figure 15 and both types of firms may find it economically feasible to use them. Indian firms may find domestic partnerships easier and more inexpensive to undergo so both high and low quality firms may use them. Therefore, they do not provide a useful indicator of ability and the client does not find them beneficial signals.

This has occurred for many of the companies with the exception of the Tata group of companies such as Tata Consultancy Services and Tata Unisys who have grown at phenomenal rates. They have grown because of their ability to collaborate with overseas companies and set up branches early in the company history. As well, these were the “pioneering firms” that Schmalensee discusses in his paper. This advantage is no better
shown than by Dr. Nirmal Jain, Senior Vice President of Tata Consultancy Services (TCS) who answered when asked why TCS grew at such a high rate, “We were there first.” They had the advantage of establishing themselves first in the industry early on and established a reputation for quality by quickly collaborating and branching. Tata Consultancy Services was established over 27 years ago and Tata Unisys entered the industry 18 years ago in collaboration with Unisys Corporation in the United States.

So why would companies bother joining hardware groups or larger holding companies if it seems to hurt their growth in the industry? The highly successful Wipro Systems Limited, the sixth largest company in the export market shows an example of this case for the HWGROUP variable. The software work was done as a part of implementing the communication hardware that they developed. The prime focus of the work was hardware, not software and the software was done only so far as it was needed to implement the hardware. Therefore, the growth or decline of the software portion of Wipro depended on the type of hardware that they developed. This explains a portion of the negative growth in the HWGROUP variable. The GROWTH variable for the HWGROUP companies reflects the growth of the software portion of their work not hardware and software combined. The companies who are members of larger groups of companies also tend to have similar characteristics. The holding groups may set up the companies to do software work for other group members. Therefore, the growth in their software revenue may depend heavily on the type of work that other members of their groups need. Again, they may not focus on their software revenues but on growth of their other companies using software implementation and development.

**Structural Stability of the Model**

An important thing to examine is if this empirical model developed above remains stable among different subsets of the data. In other words, does this model apply both to small and large companies? Do the coefficients in the model differ between older
companies and younger ones? or is the model applicable to all types of firms? The Chow test provides a way to test this (Gujarati 1995).

What I want to see is if the empirical model undergoes a structural change between different subsets of the data. In other words, I am trying to see if the parameters of the model such as \( \alpha \) or the \( \beta \)s change between these subsets. If they change, a separate model must be estimated for the particular subset of the data. If not, the entire sample can be estimated with one single model. The Chow test simply uses the F test with the residual sum of squares from the individual, subset regressions and the combined regression. The data are first separated into two subsets of data containing \( n_1 \) and \( n_2 \) observations which are hypothesized to be structurally different. The residual sum of squares for the combined regression, \( S_1 \) is found. Then each subset is used to estimate the model and the residual sum of squares, \( S_2 \) and \( S_3 \) are found for each subset. These two are then added together and become \( S_4 \). \( S_5 \) is then found by subtracting \( S_4 \) from \( S_1 \). The F test for the Chow test is then

\[
F = \frac{S_5 k}{S_4 (n_1 + n_2 - 2k)}
\]

If the F value exceeds the critical value of F, the null hypothesis that the parameters are the same is rejected. In other words, we reject the hypothesis of structural stability.

The data was put into logical subsets that might not be structurally stable and the results are shown in figure 20.

<table>
<thead>
<tr>
<th>Subset 1</th>
<th>firms &gt;10 years old</th>
<th>firms &gt;100 employees</th>
<th>firms doing international work</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subset 2</td>
<td>firms &lt;10 years old</td>
<td>firms &lt;100 employees</td>
<td>firms working in domestic only</td>
</tr>
<tr>
<td>F Chow test</td>
<td>1.002</td>
<td>0.4142</td>
<td>.9732</td>
</tr>
<tr>
<td>F critical</td>
<td>2.4</td>
<td>2.4</td>
<td>2.4</td>
</tr>
<tr>
<td>df numerator</td>
<td>11</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>df denominator</td>
<td>336</td>
<td>336</td>
<td>336</td>
</tr>
<tr>
<td>Result</td>
<td>fail to reject</td>
<td>fail to reject</td>
<td>fail to reject</td>
</tr>
</tbody>
</table>

Figure 20: Results of Chow Test
In all subsets, we fail to reject the null hypothesis that the model differs. Therefore, the empirical model remains structurally stable for all types of firms across the dataset and we can apply it to any firm in the industry. This is a powerful result of the model indicating that it may have explanatory power for all types of firms.

Implications of Study

Returning to the first question of this paper, what kind of industries develop in third world countries? This paper focuses on the rapid growth of firms in India’s software industry. Can we cross apply this experience to other countries? The software industries in developing countries need two things before applying any of this analysis. First of all, there must exist skilled software professionals that can do software work according to the needs of an international client (or can learn to do so). Secondly, some type wage differential must exist between the programmers in the developing country and their western counterparts. In this paper, it was taken as given that skilled professionals existed in the market and firm growth depended on lowering the asymmetric information between existing firms and their potential clients.

International relationships play a large role in the development of this industry because they both provide signals to potential western clients and allow the Indian company to learn from their partner. However, western software companies will only collaborate if they find it profitable to do so. This occurs when they can use the Indian companies to make money not only in the international market but also in the domestic market through agency operations. Again, this profitability relies on the assumption that a sufficient amount of skilled programmers already exist because if they did not, there would be no reason for the foreign software company to believe that the Indian company will make any money. These international relationships also provide a large amount of funding to increase the signaling in the international market by methods such as creating overseas branches and specialties in particular sectors or technologies.
The notion of agency operations implies that some type of viable domestic market must exist. As noted earlier, NIIT relied heavily on foreign partners for their growth in the industry. Companies joined them because they promised to help the companies sell their products or services in the domestic market. A domestic industry is also crucial because entrepreneurs can begin in the domestic market and then venture internationally. Five business school students with only classroom knowledge of computer programming started Mastek. They ventured into the international market only after working domestically for five years. (Desai, 1994).

Now even if these parameters such as skilled and inexpensive software talent and a potential domestic market are in place, how can the government help increase the growth software industry? Remember that Indian companies will grow because they signal in a way that allows clients to find them within a low level of search effort. Therefore, the government can simply help the Indian companies signal their abilities easily. In India, the government has successfully undergone large scale marketing efforts in other countries through brochures and conventions. They also provide easy means for smaller companies to disseminate information through the creation of the Software Technology Parks. These parks provide a method for smaller companies to signal internationally by providing basic communication links and supplies to enter the industry easily. The Export Processing Zones have lowered the cost of importing hardware and provided tax breaks for companies engaged in 100% export work. This further reduces the cost that foreign companies incur in collaborating with Indian firms. The recent liberalization of the economy also allows international companies to enter the industry easily. As well, the Indian government has helped many companies signal quality by providing simplified procedures for ISO 9000 certification.

**Future of the Industry**

As the industry progresses, more firms will have the ability to signal and foreign firms will become more comfortable using Indian software firms. The number of firms
that have either fully signaled to a bulk of their potential market or have proven their abilities through previous work will increase. Many Indian firms will also have long standing relationships with a number of western firms. All these factors considerably lower the search effort that clients have to spend in finding an Indian company to match their needs.

Because of the increase in reputation due to a history of effective signaling and lowering of transaction costs, western firms, banks, and venture capitalists have been trying to fund new Indian software start-ups which helps the start-ups invest in international signaling efforts. This type of funding by well-known venture capitalists and investment banks may also be a new signal that acts in a similar way to collaborations. If the western bank or venture capitalist has been successful in starting up companies in the past and then funds an Indian start-up, western firms may feel more comfortable using the new company. This is another example of the model discussed earlier. Only quality companies will find it economically feasible to signal internationally through these means since venture capitalists fund only high quality start-ups.

The domestic software industry which historically lagged the international one has been fast at catching up with growth rates of 40-50% over the last few years (Mehta 1995). The domestic level of hardware including multi-user systems, servers, and single-user systems has increased over 64% between 1994 and 1995 (Malhotra Aug. 1-15, 1995). As western companies clamor to gain market share in this rising Indian market, Indian firms continue to undergo successful collaborations and agency operations. As well, the rise of the domestic market allows smaller companies to enter and gain significant expertise and specialization by starting locally.

The largest firms who have been in the industry for a long time and have already signaled to a bulk of their market still have the potential to grow if they use their experience to move into higher end work such as software packages. The growth of the domestic market helps this movement since the firms can sell their packages at home.
before venturing internationally. Dr. Nirmal Jain, Senior Vice President of Tata Consultancy Services, the largest software company in India, related that TCS has the potential to move into this market since it has learned much from the failure and problems of earlier packages. It has recently been successfully selling its financial accounting package, EX in the domestic market.

The current growth in the Indian software industry has been so great that the increasing demand for Indian programmers has been driving up their wage and increasing the cost of Indian software projects. Does this mean that the Indian software industry may lose its competitive edge? Although this wage differential has provided a basis for the start and rise of the industry up until now as I described in this paper, the long standing relationships, gain in reputation, and quality of work which has increased during this evolution may outweigh the closing wage gap. As described in earlier models, the closing wage gap leads to a lower search effort by western firms but up until now, Indian firms have been able to establish strong signals and long standing reputations that have made these searches successful. Although these models provided a good explanation of the start and growth of the industry, perhaps future models should include other factors for using Indian companies in addition to wage differentials.
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