Information Technology and Business Transformation: Work Location and the Allocation of Decision Rights

by

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M.S., Technion
B.S., Technion

Submitted to the Alfred P. Sloan School of Management in Partial Fulfillment of the Requirements for the Degree of

Doctor of Philosophy in Management

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

September 2004

July 2004

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Abstract:

This thesis examines the relationship between IT investments and the transformation of business practices and organizational structure. In particular, I consider the impact of IT on the location of work and on the allocation of decision rights. I first study how a firm's IT intensity can affect its ability to exploit regional cost differentials and locate in lower-cost areas. I develop a framework to analyze the effects of IT on the regional distribution of work for a homogenous set of Fortune 1000 manufacturing firms. I estimate the regional demand for customer-service representatives by firms using firm-level data. The framework is a discrete choice model in which regions play the role of differentiated products. I allow for flexible substitution patterns between regions by using random coefficients. The latent variable of the model, the firm's profits from customer care, is derived from the premises of a queueing (stochastic) process. The estimated demand structure is used to assess the effects of information technology on customer volume, location choices and cost savings. The results confirm the higher cost sensitivity of IT-intensive firms, but also suggest that the ability to exploit cost differentials is highly firm-specific and that the importance of geographically-localized externalities does not vanish. I then develop and test a model to analyze how the allocation of purchasing decision rights across geographically-dispersed business units influences their IT investment choices. Since the productivity of many information technologies (in particular communication technologies) relies on network effects in which the marginal productivity of the adoption of a technology by a site is higher if the rest of the firm adopts this technology as well, firms have an incentive to require coordinated investments in technology across the enterprise. Still, research in IS has also highlighted the fact that the productivity of computer investments is highly dependent on co-investment in complementary assets (for instance, tacit knowledge and specialized work processes). Many of these additional investments are intangible and highly dependent on the local expertise and the knowledge of the branch or division. When local knowledge is important, the uninformed headquarters have an incentive to delegate decision rights to the local branch. I develop a mathematical model to analyze this tradeoff and derive testable hypotheses that relate IT investment diversity and the allocation of decision rights. Decentralization leads to less uniform IT investments and is more likely the less vertically integrated the firm is. I also provide some empirical support for these hypotheses using a large dataset of firms' IT investments and allocation of purchasing decision rights.

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Acknowledgments

This thesis is made possible by the support of many advisors, scholars, friends and family. My doctoral committee of Erik Brynjolfsson, Tom Malone and Peter Weill has provided help, insights, support and guidance both in shaping the content of this thesis and in navigating the sometimes murky waters of the PhD program at MIT. Of course, all remaining errors and shortcomings remain my responsibility only.

I was fortunate to work in the wonderfully dynamic and challenging environment of MIT that encourages originality, independent thinking and path-breaking research. In particular, I am grateful to the IT faculty, Erik Brynjolfsson, Chris Dellarocas, Benjamin Grosof, Stu Madnick, Tom Malone, Wanda Orlikowski and Peter Weill, as well as my fellow current and past doctoral students Sinan Aral, Jeffrey Hu, Tanu Gosh, Michael Zhang, Aykut Firat, Nils Fonstad and Avi Bernstein for their support in creating the foundations for a vibrant research community in the small IT group at Sloan. Many of these people are (or were) affiliated with the three main centers in IT research at Sloan: the MIT Center for eBusiness, the Center for Information Systems Research and the Center for Coordination Science. All three centers have been - and still are - a wonderful forum for exchanging ideas and conducting investigative research in IT. I am particularly grateful to the current and past research scientists and administrative assistants of these centers: David Verrill, Stephanie Woerner, George Herman, John Quimby, Mark Klein, David Fitzgerald, Debie Thomas-Szabo, Yubettys Baez and Robynne DeCaprio. Special thanks to the support staff at Sloan, and in particular Claudia Forero, Joan Wingo and Anna Piccolo. Your support of the PhD students is invaluable and deeply appreciated. Last but not least, I want to thank Sharon Cayley for her efficient behind-the-scenes work in smoothing out the bumps on the PhD program road and for just being there when needs arise.

The research environment and educational process of earning a PhD was made possible thanks to many sources of funding. My research has benefited from the generous support of the CSK Corporation, Japan through the Center for E-Business at MIT. The financial support provided during the last two years of my work by CSK was particularly helpful. I am also grateful to the NSF (grant #IIS-0085725) for summer support, and to the MIT Sloan School of Management in general for various fellowships.

I am deeply thankful to my family and friends for their support. Because I have been blessed to come in contact with so many wonderful people, I cannot name all the people that I wish to thank and will inevitably forget many. My deepest gratitude goes to my parents for encouraging me in my academic career despite the distance. Thank you for giving your children so much and I hope to follow your example in life. My sisters, brother-in-law, nephews and niece deserve particular thanks. Many thanks to Moshe Tennenholtz who introduced me to the academic research world and patiently supported me along the way. My friends in Boston and beyond are very important to me and I thank them for their kindness during these past five years. Thanks to David Fass, Ken Hartman, Sinan Aral for being such good friends, and to Gilbert and Miriam Trout, Noam and Chana Wasserman, R. and Mrs. Moskowitz for their wonderful hospitality, as well as to many other friends in Brighton and Brookline, too numerous to name.

I thank Igal Hendel for helping me with some technical details of the research. I have also benefited from feedback from many of the participants at the MIT Econometric Seminar.

As I was searching for an advisor four years ago, I was fortunate to come across Erik Brynjolfsson. From the very onset, Erik has been enthusiastic about the research topics I was interested in and I can truly say that this research would not have come to life without his help and unwavering support. Erik has been a wonderful advisor, a role model and will always be a source of inspiration for me. Thank you, Erik.

I am now embarking on a journey as a professor at the Graduate School of Management at the University of California, Irvine. I am confident that the tools and training that I acquired here at Sloan will be invaluable to a successful career. I thank my colleagues at UCI for helping me transition from my life as a student to my life as a professor.

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1 Introduction

Advances in information technology in the past twenty years, and in particular the widespread deployment and implementation of enterprise software together with the wide dissemination of networking technologies (the Internet) in the mid-nineties have enabled firms to leverage competitive assets across traditional boundaries, including geographical boundaries. While manufacturing has long been globalizing, information technologies and in particular communication technologies allow a new wave of globalization, in services this time. Many large IT firms for example – Microsoft, HP, IBM, EDS, CSC, Accenture, Cisco – have now moved part of their software development efforts offshore to Bangalore, India. The phenomenon is highly advertised, and hyped, to the point where some claim that any organization that does not outsource will lose its competitiveness (reminiscent of the predictions regarding e-business in the late 90's). Still, others emphasize the difficulties arising from cultural differences, time differences, language, reliability, and accountability, issues that are harder to address for services, especially the kinds that require customer interaction and personalization (Macke, 2003). In fact, during previous go-global drives, some companies ended up repatriating manufacturing and design work because they felt they were losing control of core businesses or found them too hard to coordinate (Engardio, Bernstein and Kripalani, 2003). For instance, Allegheny Energy Supply, a utility engaged in the supply of electricity and energy-related commodities, has recently moved its trading operations (a priori, a location-free activity) back to Pennsylvania in order to be closer to its physical generating plants in the Midwest and Mid-Atlantic markets.

The implications of dramatic reorganization of work are far-reaching and affect firms, workers and ultimately government policies. In fact, the backlash that outsourcing practices have generated in political spheres is testimony to how important the issue has become both to firms and the economy as a whole. But there is little systematic analysis of how much more flexible organizations have become in locating work as a result of their IT investments, and whether the simple (and perhaps simplistic) model in which the notion of the firm as an integrated whole will give way to a network of loosely coupled, footloose entities is an accurate reflection of the reality.

This thesis endeavors to analyze the effects of information technologies (if any) on the ability of firms to locate their activities efficiently. Efficiency refers to the hiring of workers with equal skills and capabilities in the most cost-effective regions. A rational firm should choose the lowest-cost region for each of its activities but may be limited in its ability to do so by its dependency on local benefits, such as proximity to customers and other markets. However information technologies may enable firms to overcome locational dependencies by providing ways to coordinate activities at a distance, globally exchanging information electronically in seconds through far-reaching large-bandwidth communication networks and allowing for communication among users across heterogeneous systems without information degradation.

There exists substantial anecdotal evidence of companies that are using a global workforce in their daily operations. Companies as varied as GE, Oracle and American Express employ workers worldwide in order to draw on a larger pool of talent. General Electric for example, employs almost 6,000 scientists and engineers in 10 foreign countries so that it can tap the world's best talent. Oracle and IBM have outsourced many of their development efforts to countries like Ireland and India. Many consulting firms have shifted some of the more routine and low-margin work to their international offices. In recent years, large securities firms have relocated many service operations in various regions of the United States: American Express placed major traveler's check and credit card processing facilities in Salt Lake City, Phoenix and Tampa. Charles Schwab located its major data center in Phoenix, while Merrill Lynch has consolidated processing operations to 3 major sites in Denver, Jacksonville, FL, and New York City. Intuitively, technology reduces the need for back-office operations to be close to the customer or corporate headquarters, prompting firms to relocate some of their activities to lower-cost regions.

However, cost is not the only factor that firms take into consideration when deciding where to locate. There are advantages to locating in specific cities where operational costs are not the lowest, advantages that derive from the proximity to large customer markets, competitors, suppliers, and to other firms providing complementary services (such as law firms, for example). It may also be harder for a firm to provide high-quality service operations when these operations are disembodied from the rest of the firm's activities. Recently, Dell Computer, a company whose business model is based on cost-savings decided to move back some of their customer service operations to Austin, TX from India following complaints from customers about the quality of service that they were receiving from the call agents in India.

The main question that this research addresses is estimating the extent to which information technologies change the relative importance of localized benefits versus unit costs in firms' location and hiring decisions. In other words, does information technology, and in particular communication-based technologies substitute for location-bound non-pecuniary regional advantages and to what extent? If IT substitutes for geographically localized information and production networks, firms that are more IT-intensive should be more flexible in the location of their activities as they take advantage of the lower cost locations. In addition, additional changes in the organizational structure of the firm may be necessary in order to coordinate geographically-distant business units. I present and test a model that provides insights into the tradeoffs that managers face when deciding whether to delegate decision rights to the local branches or centralize them at the headquarters.

In order to estimate the degree of substitution between technology and local benefits, I consider a well-defined narrow process, namely customer service. Drawing on a set of 104 Fortune 1000 firms in manufacturing, I developed a framework that allows me to analyze firms' location and hiring decisions of customer service representatives as the outcome of the optimization of a discrete choice problem. The location choices depend on the relative importance of regional benefits versus cost, and how much more a firm is ready to pay to benefit for these geographically-localized benefits. By incorporating variables that describe firms' characteristics, in particular their degree of investment in IT, this research provides quantitative estimates of the impact of IT investments on various organizational choices (and location choices, in particular) by firms.

The first chapters of this thesis are devoted to the question of how IT impacts location decisions, while the last chapter considers the potential impact of IT-driven de-localization on the organizational structure of the firm (the allocation of decision rights). The research is structured as follows: the first chapter describes the relevant literature and theoretical framework from which this research draws. I then review the literature on discrete choice models and describe the shortcomings of traditional discrete choice models. Avoiding the limitations of the traditional choice models is one of the main motivations for the framework used in this research (the use of random coefficients). Chapter 4 presents the data and develops the basic model. In Chapter 5, I explain the estimation method. As the model is highly non-linear, I resort to simulation techniques for the estimation as described in Pakes and Pollard (1989). Chapter 6 presents and discusses the results. The final chapter, Chapter 7, is concerned with the tradeoffs that arise in delegating decision rights inside firms when geographical dispersion makes coordination difficult. In this chapter, I develop a mathematical model of these tradeoffs and derive testable predictions regarding the type and magnitude of IT investments when decision rights are delegated or centralized. I then proceed to perform simple empirical tests of these predictions on a very large dataset. The estimation confirms the predictions of the model.

2 IT, Market Efficiency and Geography: Literature Review

2.1 Market Efficiency

Information technologies have often been regarded as possible drivers of organizational change both inside the firm and outside it. Indeed, the ability to process and exchange large amounts of information electronically at very low cost has far-reaching implications on the structure of firms and markets. In 1987, Malone, Yates and Benjamin examined how information technology could affect whether economic transactions are coordinated within or outside the firm. They note that each transaction can be characterized in a two-dimensional space. One dimension corresponds to the degree of asset specificity involved in that transaction (the idea is developed in general terms in the transaction-cost economic tradition such as Williamson (1975, 1985), Klein et al. (1978), and is given precise operational formalism in the theory of asset ownership of Grossman and Hart, 1986 and Hart and Moore, 1990). Assets that are highly specific to a relationship are problematic when specifying a complete – and fully enforceable – contract is impossible. If the product supplied to the client is highly specific to the needs of this client (and has therefore little value outside the transaction), a supplier will be reluctant to sink investments ex ante for fear of being held up ex post. The threat of opportunism on the side of the client leads to market failure: The investment made by the supplier is lower than what it should be without the threat of opportunism (the optimal investment in the absence of fears of ex post opportunism is what economists call the first-best outcome). In such a case, transactions are often better coordinated within the firm than in a market.

The second dimension that characterizes economic transactions is the degree of complexity involved in the transaction. The more complicated the process, the more likely coordination will take place inside the firm.

Information technologies can impact both of these dimensions. Suppose that an economic transaction is coordinated inside the firm as it entails a high degree of asset specificity and requires complex data processing activities. Information systems, such as those supporting flexible manufacturing practices, will allow firms to switch production lines more quickly, enhancing the alternative value of the asset outside the relationship and reducing the risk of being "locked" in the relationship ex-post. Similarly, large databases and query capabilities as well as automation of the production process will reduce the complexity of the task. Transactions that were formerly coordinated inside the firm will then move toward market-based coordination. In that sense, IT enables a more efficient marketplace.

Following this high-level description of how IT will affect the structure in which economic transactions take place researchers have looked at whether the markets themselves become more efficient as a result of IT. Market inefficiencies can arise from information asymmetries and information technologies can reduce these asymmetries by lowering the costs of finding information. The work of Bakos (1997) in particular describes how the introduction of an electronic market system can improve buyers' welfare by providing both price and product information to potential buyers. The availability of enhanced price information leads to Bertrand-like competition reducing sellers' margins to zero. The improved availability of product information leads to a gain in allocational efficiency due to a better match between sellers and buyers' ideal choices. In addition, electronic markets provide functions, such as settlement systems and contractual features that facilitate economic transactions. As a result of these lower search costs and enhanced transactional environments, competition increases. In these models, prices converge to zero, consumer surplus increases and markets become more efficient.

2.2 Empirical Research

Empirical research on the level of prices charged by online sellers gives mixed support to the theoretical prediction that electronic marketplaces are so efficient that sellers' profits are nil and buyers' welfare is maximized. On the one hand, Brynjolfsson and Smith (2000) did find that online retailers of books and CDs charge lower prices than their brick-and-mortar competitors. On the other hand, they also found substantial price dispersion in the prices posted by e-tailers and that this dispersion is comparable to the price dispersion found in conventional markets. Clearly, Internet markets are not as frictionless as Bakos and others predicted.

Still the effects of the Internet on price are undeniable. Brown and Goolsbee (2002) matched data on household Internet usage with data on the cost of term life insurance policies from 1992 to 1997. They found that premiums fell sharply toward the latter half of that period at about the same time a number of price-comparison Web sites came online. What's more, the faster a group of households adopted the Internet, the faster the price of term life insurance fell for that group. Premiums for whole-life insurance policies, which are not priced on the Web and were not covered by the comparison website, did not fall. A possible reason for it is that in the case of life insurance, quote sites are only a reference source. Potential customers are referred to an agent, and the actual transaction occurs off-line. But with access to the sites, consumers can get several quotes in a matter of seconds rather than hours. Not only does the web enable more efficient pricing and allocations for goods traded online, it also leads to lower prices – and presumably better match - for goods traded offline.

The effects of IT on market transactions are not always positive. The presence of both price dispersion among online merchants and lower buyer's search costs exacerbates the problem of free-riding and can potentially lead to inefficiencies. Merchants that provide complementary services in addition to the good itself cannot prevent consumers from using their services and buying the good at a lower price elsewhere. There is then a disincentive to provide these services since they do not directly generate revenue. But as manufacturers rely on brick-and-mortar retailers for the promotion of their goods, manufacturers will both limit the availability of their products online and attempt to control the pricing of their products over the Internet. In this case, the potential efficiency gains of the Internet are reduced. Carlton and Chevalier (2001) examine the decision of manufacturers to offer products online. They consider three categories of products: fragrances, DVD players, and side by side refrigerators, and find that manufacturers that limit distribution in the physical world also use various mechanisms to limit distribution online. In particular, manufacturers attempt to prevent the sale of their products by online retailers who sell goods at deep discounts. Furthermore, manufacturers who distribute their goods directly through manufacturer websites tend to charge very high prices for the products, consistent with the hypothesis that manufacturers internalize free rider issues.

2.3 Labor Markets and Location

While considerable research has been devoted to the impact of IT on consumer markets, the evidence of how the Internet affects the market for factors of production, in particular the labor market is much scarcer. An exception is a recent paper by Kuhn and Skuterud (2004) that considers the relationship between internet job search and unemployment duration. Controlling for observable characteristics among workers, the authors find that Internet searchers do not have shorter unemployment spells than non-Internet searchers. Therefore, job matching does not appear to become more efficient in terms of time through the use of the Internet by job seekers (the "sellers" in Bakos' model).

If the Internet increases the ability of consumers to search for information and results in efficient matching between buyers and sellers, a reasonable conjecture is that it will also allow firms to find and hire workers regardless of their location, leading to efficiencies in the matching of workers to jobs. Indeed, firms' hiring decisions may be non-optimal if the firm must locate its workers at - or near - its facilities. Reducing firms' dependency on location would therefore enhance the efficiency of the labor market.

There are several reasons why firms may need to hire workers in specific locations that are not necessary the lowest-cost. Research on the theory of the multinational enterprise emphasizes the existence of proprietary assets for explaining the basis for horizontal multi-plant enterprises. This approach, developed through the work of a number of authors including Caves (1971) and Hennart (1982), describes proprietary assets as the resources that the firm can use but not necessarily contract upon or sell. An asset might represent knowledge about how to produce a cheaper or better product at given input prices, or how to produce a given product at a lower cost than competing firms. Assets of this kind are closely related to the firm-specific resources in the resource-based view of the firm (Wernerfelt, 1984). These resources form the basis for the firm's competitive advantage, since they hold a revenue productivity for the firm, closely akin to product differentiation.

Proprietary assets might affect the ability of multinational firms to locate production based on production costs. In fact, Maki and Meredith (1986) pointed out that multinationals might be able to transfer production from a *low-cost* to a *high-cost* location if their proprietary assets include the ability to transfer their source-country cost advantages. Similarly, the inability of a firm to transfer proprietary assets might hinder its ability to exploit cost differences and relocate to lower-cost regions.

In that respect, the role of IT is ambiguous. If computer and communication equipment allows firms unprecedented flexibility in dispersing business units geographically, these same technologies are also associated with very large intangible investments in proprietary assets that might not be easily dispersed, such as informal knowledge networks that are location-dependent. Recent studies showed that each dollar of installed computer capital in a firm is associated with up to ten dollars of market value, suggesting very large investments in other intangible assets (Brynjolfsson, Hitt and Yang, 2002). In that case, IT could have little effect on the delocalization of tasks that are intangible-intensive and can in fact increase their relative importance.

In order to crystallize this idea, the following simple general-equilibrium model based on the Hecksher-Ohlin model of international economics describes how the relative prices of two types of services change when resource endowments change. Suppose that there are two types of services: basic services which are well-defined, repetitive tasks that can be easily monitored and adapted without physical interaction. The second type of service requires coordination among several divisions of the firm, producers and suppliers, as well as the exchange of sometimes ambiguous (tacit) and sensitive information. The first type of service is labor intensive whereas the second type of service is dependent on the assets of the firm, in particular its intangibles (for example, its reputation or some innovative business process) but does not require a large amount of labor. Let us call the first type of service *R* (routine) and the second type *S* (skilled). If a firm is limited to using local labor, demand conditions determine which point on the production function will be chosen. Consider now what happens when service *R* can be provided at a distance at a lower cost: as labor employed in service *R* becomes more abundant, output declines in locally-provided service *R* and expands in service *S*. Local service *R* discharges a lot of labor, thereby raising the rental price of the firm's intangible assets that are location-specific. As the value of the local assets increases, the firm's valuation of location becomes more important and employment in service *S* goes up as well.

This simple model shows that IT can have a positive effect on the relative value of local employment. In order to analyze these effects, an empirical evaluation of the role of IT on localization decisions is necessary.

2.4 Outsourcing

Although this question is essential in order to understand the potential of outsourcing and off-shoring in the economy, most of the previous research on outsourcing has not been concerned with location issues but rather with the contracting aspect of outsourcing business functions to a third party, building on the traditional economic frameworks of transaction cost economics. Ang and Straub (1998) studied 243 U.S. banks outsourcing decisions and the factors considered by these banks when making their decision. They found that production costs (the amount of money a customer pays the vendor for its services) is given six times more emphasis than transaction costs. Companies were focusing on achieving a production cost advantage, which is the difference between what it costs to keep a specific function in house and what a vendor charges, but neglected to take into account the potentially significant transaction costs. Their findings supported the research conducted by Gurbaxani & Whang (1991) that had already suggested that firms should perform specific business functions in-house only if the transaction costs associated with arranging for such services in the marketplace exceed the production cost savings to be achieved from outsourcing it (see also Loh & Venkatraman, 1992b; Applegate & Montealegre, 1991).

The idea that IT vendors hold considerable economies of scale in procuring IT services has led managers to "jump on the outsourcing bandwagon" (Lacity and Hirschheim, 1993): as IT spending is mostly not accounted for as an investment but as an overhead cost (last chapter of this thesis), companies are seeking to reduce these costs by outsourcing the IT function: if companies do not "maintain their own power supply", then "why shouldn't they do the same for IT?" (Venkatraman and Loh, 1994)

At the same time, researchers have become aware of the difficulties involved in managing the outsourcing relationship: Earl (1996) identified some of the problems that may occur - such as hidden costs, failure to implement new technology innovations, failure to pass on cost savings to the client, arguments regarding contract details and interpretation of performance metrics. In addition, there is a risk of loss of competitive advantage as the result of the transfer of key business or strategic knowledge from the client to the vendor.

The outsourcing of a business function is therefore subject to risks and failures, and researchers have attempted to determine how to best manage the IT outsourcing relationship (see for instance the "Four Outsourcing Relationship Types" of Kishore, Rao, Nam, Rajagopalan and Chaudhury, 2003) over time. Information technologies can help manage this relationship. As described above, coordination costs include information search costs, communication costs and monitoring costs and the Internet can reduce these costs. In particular, the ability to exchange large amounts of information quickly reduces communication costs and enables clients to monitor vendors and projects more closely, thereby offering the means to verify and enforce a contract ex-post in the event of a dispute.

Since most of the research on IT outsourcing has focused on the buyer-vendor relationship, it has naturally ignored the issues that arise from the geographical dispersion of work (between business units of the *same* firm that are geographically distant). Certainly, the emphasis on the contractual issues that are inherent in such buyer-vendor relationships is warranted, given that IT outsourcing is by definition the "contracting of various information systems functions such as managing of data centers, operations, hardware support, software maintenance, network, and even application development to outside service providers" (Chaudhury, Nam and Rao, 1995). But the more basic question of location (or rather dispersion) of work which is implicit but dwarfed by the associated contracting/incentive problems of outsourcing to a third party, has not been considered. Certainly, research on IT outsourcing yields valuable insights on how to coordinate work between firms, some of which can be applied to the coordination of work between geographically dispersed units of the same firm. The observation that IT lowers coordination costs, for example, has implications for coordinating activities both between firms and inside the firm. Other factors however are less important when dispersing work within a firm than across organizational boundaries. For instance, recent research has suggested that trust is an essential pre-condition to developing strategic alliances and partnerhips (Eisenhardt & Schoonhoven, 1997; Fitzgerald & Willcocks, 1994) but is clearly less of an issue when transactions are taking place within the same firm. If IT is found to affect trust, its impact on coordinating work within the firm will be different from between firms. It is therefore important to understand the relationship between IT and de-location independently of the ownership structure in which transactions take place.

Another aspect of the literature on IT outsourcing is that it is concerned mainly with the outsourcing of the IT function. Clearly, the insights gained by looking at the IT function are valuable when looking at other business functions, but even within the outsourcing framework, researchers have noted that circumstances, industries, and objectives matter a great deal in structuring the relationship. For instance, Marcolin & McLellan (1998) show that the nature of the IT outsourcing relationship is rooted in industry and organizational factors such as the client's business and IT objectives, the level of uncertainty in their industry as well as "interpretation strictness" -- how tightly or loosely the actual contract is observed in day-to-day practice. Therefore, both the structuring of the outsourcing relationship and its management may be different for business functions other than the IT function.

2.5 IT and Business Process Automation

Whether outsourcing, off-shoring or de-locating work among different business units, companies face the issue of how to define the processes that they are "exporting" to distant geographical areas so that they can still remain integrated with the remainder of the firm's business. In that respect, IT has a dual role: on the one hand, fast communication of large amount of information enables various organizational units to exchange up-to-date information and act upon this information in real-time. The exponentially decreasing costs of communication render the strategy of coordinating work across many different locations feasible and efficient. Similarly, lower costs for faster central processing units, large data storage systems and enhanced multimedia capabilities make it cost-effective to computerize even the most basic business functions, which can then be sited anywhere.

On the other hand, IT and the automation process with which it is associated require processes inside the firm to be clearly defined, monitored and managed. In fact, in a recent survey of large manufacturing firms (reported at the end of this thesis), a majority of respondents cited "visibility" as one of their main objective in implementing a large enterprise-wide computerization effort. While information systems may constrain their users by imposing specific ways of doing things, they also help for the same reason, structuring, defining, and representing the informal and (often) poorly-structured processes on which work is based. Simon (1960) noted that it is sometimes possible to extend the extent of computer substitution by simplifying the task. In other words, complex tasks can be broken down into simpler tasks, which can then be described using rule-based logic and step-by-step instructions. Conversely, for a task to be automated, it will need to first be described in procedural steps. For instance, Levy and Murnane (2004) describe how a mortgage underwriter processes applications using explicit rules. There is a rule governing the maximum loan size, a rule that includes test on the applicant's liquid assets, job tenure, monthly income etc… More flexible rules can be designed by assigning points to various items, so that the underwriter calculates a weighted score on the basis of which the decision to grant the mortgage is taken. Structuring a process so that it can be expressed in terms of premises and logical rules is a pre-requisite to automating it.

2.6 The Death of Distance

In such an environment, one might predict that computers will lead to what has been hailed as the "death of distance" (Cainrcross, 1997). Sassen (1998) considers what the death of distance means for government/businesses structures and how citizens perceive the world. Building on Beninger (1989) and Yates (1993)'s work on communication in organizations, she explores how the death of distance both allows management-at-a-distance and encourages concentration of elites within the 'latte belt'.

Management-at-a-distance requires the use of computerized systems and of the Internet, in particular, to both find and set up the most cost-effective allocation of labor across geographical regions, as well as to coordinate this work seamlessly across the enterprise. The explosion of such computer-based systems and the dramatic decrease in their costs naturally suggests that firms will be increasingly capable to "free" themselves from the tyranny of location (Blainey, 1966).

2.7 The Economics of Location

Yet economists have long realized that location decisions entail externalities. In fact, agglomeration patterns in the "new economic geography" models (Krugman, 1991, Fujita, Krugman and Venables, 1999) are based on the presence of pecuniary externalities. The characteristics of these models include consumers with preferences for diversity in consumption, monopolistically competitive firms producing differentiated products, increasing returns to scale at the firm level and transportation costs. In these models, agglomeration arises from a self-reinforcing loop: locations with high demand for a good attract producers of that good, which in turn require additional employees, generating even higher demand for all goods at that location, making it even more attractive to other producers. Moreover, as consumers value diversity, they prefer to live in a city where many producers have located so that more variety is available at lower prices.

The presence of externalities linked to location patterns provide an intriguing way to account for some of the productivity growth in firms and in the economy. Standard economic models of growth (the neo-classical growth model of Solow (1956) and Swan (1956)) posit a production function with two inputs, labor and capital, and an additional term, the total factor productivity (also called the Solow residual). In this type of models, growth in a firm or in the economy is either determined endogenously by growth in factors of production, depending on the saving (and therefore consumption) choices in the system, or exogenously by growth in the total factor productivity. In the neo-classical growth model, output growth that is not explained by input growth is externally determined by changes in this productivity term. For instance, technological change is not explained in the neo-classical growth model but is accounted for solely in the TFP factor. In an attempt to explain technical change, economists have proposed new models of economic growth in which output growth is directly related to the growth in the TFP. In a series of papers, including a famous one in 1962 with J.A. Mirlees, Kaldor posited the existence of a "technical progress" function such that per capita income was indeed an increasing function of per capita investment. Thus "learning" is regarded as a function of the rate of increase in investment. The more an economy (or a firm) invests, the more learning it will generate. Similarly, Arrow (1962) took on the view that the level of the "learning" coefficient is a function of cumulative investment (i.e., past gross investment). In this specification, investment does not only induce productivity growth of labor on existing capital (as Kaldor would have it), but it also improves the productivity of labor upon all subsequent machines made in the economy. If firms face constant returns to scale for all inputs together (as in a Cobb-Douglas production function), it might seem as if output per capita and consumption per capita does not grow unless the exogenous TFP factor grows too (a central part of the Solow model which is supported by the facts). However if knowledge, as Arrow argued is common to all firms (a free and public good) there will be increasing returns at the level of the economy. In other words, there are externalities to knowledge accumulation in the economy that are not internalized individually by firms.

In this model (and the models that follow such as Romer, 1986) the nature of the externality is in knowledge creation. But we have seen above that location is also a source of externalities. In fact, several other economic models also describe the externalities that arise from location decisions. In production externality models for instance, firms' production possibilities depend on the actions of other firms at the same location via knowledge spillovers (see for example, Berliant, Peng and Wang (2002), Fujita and Ogawa (1982), Henderson (1974, 1988)). Firms want to locate their activities where other firms are because they derive benefits from this proximity. Similarly, natural advantage models emphasize differences in resource endowments between regions: certain regions are then more attractive to certain types of producers. Firms that value a particular feature, such as proximity to a body of water or soil will concentrate at locations with more of that feature.

Empirical research has shown that these externalities are economically significant. Ellison and Glaeser (1999) looked at four-digit manufacturing industries and found that industry location can be explained in part by resource and labor-market natural advantages (costs). For some highly agglomerated industries though, inter-firm spillovers are found to be much more important (the fur industry for instance, the most agglomerated industry in their sample, is concentrated in the New York area). Accounting for these types of externalities is important in studying the possible substitution effects between IT and location. If firms benefit from agglomeration economies, the Internet may not substitute for the advantages of cities. Kolko (1999) used data on domain-name (web) density in metropolitan statistical areas of the US to show that city size is positively associated with the use of the Internet, suggesting that the two are complement, not substitutes. In addition to a positive relationship between city size and domain density, the author finds that isolated cities have higher domain density: remote cities benefit more from the web. These findings suggest that web usage and face-to-face communication are complementary and not substitutes, but that the Internet may substitute for longer-distance, non-electronic communication.

In this vein, Leamer and Storper (2001) discuss the ambiguous impact of IT in changing location patterns. Building on the historical perspective of how lower transportation costs enabled the dispersion of routine activities but also increased the complexity and time-dependence of productive activity (therefore favoring agglomeration), they argue that the Internet will produce similar opposite forces. They note that "it is common for specialized immaterial producers to have branch offices in major cities, near the location of deployment of (these) ideas, suggesting that the "shipping" of an intellectual product may be as costly as shipping a tire axle." Trust, understanding and informal relationships require complex uncodifiable messages that are hard to transmit over electronic media. Similarly, new products incorporate an extensive amount of complex uncodifiable information.

In support of this hypothesis, Saxenian (1996) studies the organization of production in California's Silicon Valley and other technology regions. She argues that Silicon Valley surpassed its East Coast counterpart in the 1980s because the region developed an industrial system that enabled businesses to be more flexible, adaptive and innovative. The rich social, technical and productive relationships in the region fostered entrepreneurship, experimentation, and collective learning. As a result, the region's infrastructure was as critical to the successes of local firms as their own individual activities.

2.8 Summary

This chapter has reviewed the literature concerning the impact of IT on the efficiency of consumer markets and argued that the findings of this literature may be applicable to labor markets. In labor markets, as in consumer markets, there exist market frictions that shift the market equilibrium away from the intersection of supply and demand (i.e., the competitive equilibrium). In the case of factors of production, one needs to consider both how IT impacts work inside firms (including the automation of tasks) and how firms rely on the externalities they derive from their factor location choices which might lead to a non-competitive equilibrium. The chapter provided a short review of the literature on each one of these topics. The next chapter presents the statistical background on which the estimation in this research builds.

3 Discrete Choice Models

In order to estimate the relationship between firm's IT investments and location decisions, I used data about location characteristics, firm characteristics and decision choices for a sample of 104 firms. The statistical framework used in this research is based on a model of choice by firms. This chapter presents the background necessary in order to understand how choice models work and what the assumptions underlying these types of models are.

3.1 Overview

Firms face decisions every day. Examples of production choices include choice of a technology, the product lines to produce, the output levels of these product lines, the input mix needed to achieve these levels, the marketing (pricing, advertising expenditures) strategy. Among the production decisions that firms must make is the decision of where to locate workers. Typically, this decision will depend on a variety of factors, one of them being the unit costs of an additional worker in a specific location. Suppose that the outcome of this decision is denoted as y, a vector that specifies the number of workers hired in each possible location. Since the number of workers and the set of options (locations) are finite, this is a discrete choice problem. A possible value for this vector for example could be a hundred workers in Iowa, fifty-six workers in Massachusetts, and none in any of the other possible locations. Our goal is to specify the behavioral process that leads to these choices.

The basis for discrete choice models is the assumption that behavior depends on the characteristics of the alternatives and not on each alternative per se. The dimensionality of the choice problem is therefore reduced to the dimensionality of the set of characteristics. This approach (pioneered by Lancaster, 1966) states that it is the attributes of the goods that determine utility, not the goods themselves. Unfortunately, we cannot completely specify the exhaustive set of characteristics that influence firms' location and hiring choices. Some factors are idiosyncratic to the firm and simply not observable by the researcher: for instance, management characteristics or special incentives given to a firm in order to locate in a specific region are not observable. Luce (1959) and Marschak (1960) introduced the concept of random utility in consumer choice to capture the fact that utility is intrinsically probabilistic since some of the attributes that determine the choice are not observable by the researcher. The attributes (observable and unobservable) relate to the firm's choice through a function $y = h(X, \varepsilon)$ where X are the observable factors and ε are the unobservables. Notice that the function is deterministic if both X and ε are known. If ε is not observed though, only the probability of a choice vector y can be estimated, not its exact value.

Discrete choice models place various distributional and independence assumptions on the unobservables so that the probability that the firm will choose a specific location and hiring decision is determined by the probability of the unobserved factors, given the observed characteristics.

A choice model relates the characteristics of the choice situation to the choice made by the decision maker through the function h. In this sense, h is simply the mapping between the value of the attributes of the alternative and the decision. The mechanics of choice however involve a latent variable which in consumer choice models corresponds to the utility the consumer derives from each alternative (or in the case of a firm the profit of the firm from choosing the alternative). Decision makers maximize this latent variable (utility or profit) and the choice y represents the outcome of this implicit optimization process. A discrete choice model can thus be thought of in terms of utility-maximizing (or profit maximizing) on the side of the decision maker. The (indirect) utilities are latent variables and the actual choice, which is observed, is directly related to the underlying (unobserved) utilities. Note that although the derivation of the choice probabilities is consistent with utility maximization it may also be consistent with other forms of behavior.

3.2 The Mechanics of Discrete Choice Models

To understand how discrete choice models work, consider a decision maker who faces J alternatives. If the decision maker chooses one of the alternatives, it will derive a certain utility from this choice. Given that we do not observe all the attributes that enter the choice, we cannot observe the utility (or profit) from that choice. However, since we know which alternative was chosen, we also know that the utility, factoring in the unobservables, was higher for that alternative than for any other alternative. Therefore, conditional on the value of the observed variables, the probability that an alternative is chosen is determined by the distribution of the unobserved component of the utility. The nature of the distributional assumptions placed on the unobserved component of the utility lead to different types of choice models. Logit models for instance, assume that these components are distributed independently and identically across alternatives and decision makers and follow the type I extreme value distribution.

Once the unobserved portion of the utility is specified, the choice probabilities of each alternative follow. Indeed, the probability of choosing one alternative over another is simply a function of the difference between the two random components of the utility of each alternative. Given the distributional assumptions placed on these components, the probability is fully characterized, up to a multiplicative and additive constant.

The utility that a decision maker derives from alternative *j* is $U_j = V_j + \varepsilon_j$, where V_j is the representative utility and incorporates the observed attributes of the alternative, and ε_j is the random term among the population and is not observed. This decomposition is fully general and simply states that ε_j is the difference between the true utility U_j and the part of the utility V_j that we can observe. The distribution of ε_j will then depends on the specification for V_j. Denote the joint density of the vector $\varepsilon = <\varepsilon_1 \ldots \varepsilon_J>$ by $f(\varepsilon)$, then the probability that alternative *i* is chosen is given by:

$$\begin{aligned} P_i &= \Pr(U_i > U_k \forall k \neq i) = \Pr(V_i + \varepsilon_i > V_k + \varepsilon_k \forall k \neq i) = \Pr(\varepsilon_i - \varepsilon_k > V_k - V_i) \\ &= \int_\varepsilon I(\varepsilon_i - \varepsilon_k > V_k - V_i) \forall i \neq k) f(\varepsilon) d\varepsilon \end{aligned} \quad (1)$$

where *I(.)* is the indicator function equal to 1 when the expression in parentheses is true and 0 otherwise. This multidimensional integral takes a closed form for certain specification of the distribution of the error term. For instance, the logit model is derived under the assumption that the components of ε are distributed i.i.d extreme value. The critical part of the assumption is that the unobserved factors are uncorrelated across alternatives and have the same variance. Another model, probit, assumes that the error term is multivariate normal. The advantage of a probit model is that the variance/covariance matrix is not restricted and can capture any correlation pattern or heteroskedasticity across alternatives. The disadvantage is that whereas the logit model has a closed form for the integral in (1), probit does not admit a closed form and the resulting integral must be evaluated numerically or through simulation.

Under the logit assumption, McFadden (1974) showed that the integral in (1) can be reduced to the following simple form:

$$P_i = \frac{e^{V_i}}{\sum_j e^{V_j}} \qquad (2)$$

Note that P_i has all the properties of a probability: it is necessarily between zero and one, is asymptotically 0 when V_i tends to $-\infty$, and sums up to 1 across all alternatives.

3.3 Independence from Irrelevant Alternatives

The assumption of independence in the logit model is sometimes inappropriate. For example, a person who dislikes traffic jams when driving her own car may have the same reaction to taking the bus, as opposed to commuting via underground rail. The problem is that the independence assumption between the unobserved components of the utility implies proportional substitution patterns across alternatives, given the specification of the representative utility. When the value of an alternative improves (i.e., one observed attribute that positively enters the utility increases) the probability of choosing this alternative rises. Since the probabilities sum up to one, some people who would have chosen other alternatives will switch to this alternative. Substitution patterns capture the extent to which the introduction of a new alternative draws customers away from another alternative. Substitution coefficients also reflect the shape of the demand function. In the logit specification, substitution patterns are restricted: this feature is called the independence from irrelevant alternatives.

In order to understand what independence from irrelevant alternatives is, consider two alternatives and the associated probabilities of choosing these alternatives in a logit model. Given the functional form of the probabilities, the ratio of these probabilities is independent of any other alternative (the denominator in (2) cancels out). As a consequence, the relative likelihood of choosing one alternative over another does not change no matter which other alternatives are available. Chipman (1960) and Debreu (1960) present situations when the IIA property is not realistic. The most famous example is the red-bus-blue-bus problem. A traveler faces two possible ways to get to work: either take a red bus or drive. Assume that the representative utility (the part of the utility function that depends only on observable attributes) for the two modes of transportation is the same. In this case, the ratio of the two probabilities (taking the bus versus driving) is one. If a new alternative – a blue bus – is introduced, the traveler must have the same preferences for the red or the blue bus, so that the ratio of the probability of taking the blue bus to taking the red bus is one. However, the logit model implies that the ratio of the probabilities between two alternatives does not depend on which other alternatives are available. Therefore, the ratio of probabilities between driving and taking the red bus remains one. Given that both the ratio of probabilities between driving and taking the red bus and the ratio of probabilities between taking the blue bus and the red bus are one, the three probabilities (taking the red blue, the blue bus and driving) after the introduction of the new alternative "red bus" must be 1/3. It is however much more realistic to expect that the red bus will not change the probability of driving. In other words, a much more realistic pattern would be for the probability of driving to remain 1/2, and the probability of taking each of the buses to be 1/4. In this case, the logit model overstates the probability of taking a bus and understates the probability of driving.

In general, if the ratio of probabilities (how much more likely one is to choose alternative A over B) changes with the introduction or change of another alternative, the logit model is inappropriate. This will happen if the new alternative is expected to reduce the number of people choosing A by a greater proportion than it reduces the number of people choosing B. The same issue is apparent when one looks at the cross-elasticities of substitution of the logit probabilities. It is easy to see that the elasticity of P_i with respect to an attribute z_j that enters the utility of alternative j is $E_{i,z_j} = -\beta_z z_j P_j$, where z_j is the attribute of alternative j that changes and β_z is the coefficient on z_j in the utility function for alternative j. Notice that this cross-elasticity is independent of i: the substitution away (or into) i resulting from a change in the utility of j is the same for all i. It also implies that alternative j draws proportionately from (or, in the case that the utility of j increases, contributes proportionately to) all the other alternatives equally.

3.4 Alternative Modeling

This shortcoming has led to the development of alternative models that preserve the extreme-value distribution without assuming full independence between alternatives. The Generalized extreme-value (GEV) models allow correlation in unobserved factors over alternatives. The most commonly used model of this family, the nested logit model (Ben Akiva, 1973), partitions the alternatives into subsets, or *nests*, such that the assumption of independence from irrelevant alternatives is preserved between alternatives that belong to the same nests but not, in general, between alternatives in different nests. The nested logit model is obtained by assuming that the vector of unobserved utility ε has cumulative distribution

$$\exp(-\sum_{k=1}^{K}(\sum_{j\in B_k} e^{-\epsilon_j/\lambda_k})^{\lambda_k}) \qquad (3)$$

λ_k is a measure of the correlation between alternatives in nest k. Notice that as λ_k gets close to 1, the correlation decreases, and when $\lambda_k = 1$, all the alternatives in nest k are independent. In this case the model collapses to the standard logit model. More complex forms allow essentially any pattern of correlation. The usefulness of nested logit models arises from the fact that one can easily derive a closed-form expression for the probabilities (see Ben Akiva, 1973):

$$P_i = \frac{e^{V_i/\lambda_k}(\sum_{j\in B_k} e^{V_j/\lambda_k})^{\lambda_k-1}}{\sum_{l=1}^{K}(\sum_{j\in B_k} e^{V_j/\lambda_l})^{\lambda_l-1}} \qquad (4)$$

Does independence from irrelevant alternatives hold for nested-logit models? The ratio of the probabilities of two alternatives *i* and *m* depends on whether they belong to the same nest or not. If *i* and *m* are in the same nest, then the ratio is only dependent on these two alternatives. If *i* and *m* are not in the same nest, the ratio of probabilities depends on the attributes of all alternatives in the nests to which *i* and *m* belong. Therefore, nested logit relaxes the independence from irrelevant alternatives by allowing dependence between nests. Still, nested logit retains the assumption of independence from alternatives in nests not containing *i* and *m*.

Nested logit models are still limited in a number of ways: first, one needs to decide how to allocate the alternatives between nests and levels. Clearly, alternatives should be grouped according to how similar we believe they are on the unobserved characteristics. But by definition, we cannot know exactly whether the grouping is appropriate (since the characteristics are unobservable). To address this issue, some more recent work on nested logit allows alternatives to overlap between nests (Vovsha, 1997). A more serious limitation however that is inherent to both the logit and the nested logit models is their inability to represent variations in taste between decision makers. This is an important restriction: the value that decision makers place on each attribute of the alternatives is often dependent on the decision maker. For example, when choosing a residential area in which to live, some people may prefer quiet neighborhoods whereas others will enjoy living in a vibrant lively neighborhood. Logit models (and by extension, nested logit models) cannot represent random taste variations. The following class of models, the probit models, can deal with random taste variations.

3.5 Random Taste Variation

Probit models are derived under the assumption of jointly normal unobserved utility components. As for the logit specification, utility is decomposed into observed and unobserved components, but since the density of the unobserved component is normal, the integral in (2) does not have a closed form. It must therefore be evaluated through simulation. The flexibility of the model however allows for any type of variance-covariance matrix. Since the independence of irrelevant alternatives property was associated with the restrictions of the logit model on the distribution of the error term, probit, by relaxing these assumptions allows the researcher to specify and estimate any substitution patterns. Substitution coefficients are obtained by estimating the variance-covariance matrix of the unobserved component of the utility. The main advantage of the probit model is that it can incorporate random tastes via random coefficients (Hausman and Wise, 1978). Random coefficients arise when the coefficients that affect the observed portion of the utility are not fixed but are distributed in the population according to some distribution whose parameters are to be estimated. In other words, tastes are not identical across decision makers in the population but are distributed according to some predetermined distribution. In this case, the utility of alternative *j* can be represented as $U_j = b'X_j + \beta_j X_j + \varepsilon_j$ where *b* is the mean of the random coefficients β, X_j are observable attributes and β_j is the deviation of the random coefficient from its mean *b*. The last two terms are random. Note that if β and ε are normally distributed the unobservable component $\beta_j X_j + \varepsilon_j$ is also normal. In this case, the model is simply a probit specification with restrictions placed on the unobserved component of the utility (the variance-covariance matrix). In particular, the covariance matrix of the unobserved components depends both on the covariance of the β and on X_j. As a result, the covariance differs over decision makers.

3.6 Discrete Choice Models in the Empirical Literature

Discrete choice models have been used in many applications since they were introduced in the late seventies (Heckman, 1978, Dubin and McFadden, 1984). Most of the applications of discrete choice models are concerned with analyzing consumer choice. An early example of the power of these models was given by McFadden et al. (1977). The authors applied logit models to predict commuters' mode choices in the San Francisco Bay area. A new rail system, the Bay Area Rapid Transit (BART) had been built and mode choice models were estimated on a sample of consumers to determine the factors that enter commuters' decisions, including the value of time savings. The models were then used to forecast the choices that the sampled commuters would make once BART became available. After BART was open, the commuters were re-contacted and their mode choices were observed. The predicted share of commuters taking BART was compared with the observed share. The models predicted quite well, far more accurately than the procedures used by BART consultants who had not used discrete choice models.

The most prominent usage of discrete choice models is in analyzing differentiated product markets. Discrete choice models allow the estimation of supply-demand models in markets with product differentiation in which consumer utility depends on product characteristics and individual taste parameters. Berry at al. (1996) estimate cost and demand effects of airline hubbing: a hubbing airline's ability to raise prices is focused on tickets that appeal to price-inelastic business travelers. These travelers, who favor the origin-hub airline, are found to be ready to pay an average premium of 20% for flights originating from the hub.

A market to which discrete choice models have been extensively applied is the automobile market. Lave and Train (1979) used a multinomial logit model that includes variables such as household attributes, vehicle characteristics as well as gasoline prices. Manski and Sherman (1980) developed multinomial logit models for the number of vehicles owned and vehicle type choice: they specify separate models of automobile type choice for households with one or two vehicles in their fleet. Mannering and Wilson (1985) model the number of vehicles, vehicle type and vehicle usage in a nested logit framework. In the first level, consumers decide on the number of vehicles and vehicle types. The second level includes continuous vehicle usage variables from earlier time periods. The estimation is restricted to single or two-vehicle households. Both papers assume an extreme value distribution for the error term so that nested logit models can be used. In a seminal paper, Berry, Levinsohn and Pakes (1995) provide a complete demand framework for the automobile industry that incorporates choice models with random coefficients using aggregate data. This framework enables one to obtain estimates of demand and cost parameters for a class of oligopolistic differentiated products markets. These estimates can be obtained using only widely available product-level and aggregate consumer-level data, and they are consistent with a structural model of equilibrium in an oligopolistic industry. Applying these techniques, the authors obtain parameters for essentially all automobiles sold over a twenty year period.

In a different domain, Train, McFadden and Ben-Akiva (1987) analyze the demand for local telephone service options (for example, between flat-rate and measured service) and the interrelation of these choices with the number and average duration of local calls households make at each time of day to each geographical zone. In order to perform the estimation on a randomly selected subset of the households' calling patterns, they assume an extreme value distribution of the error terms and specify choice behavior in a nested logit framework. This enables them to calculate elasticities of demand for each local service option, number of calls, average duration, and revenues, with respect to the fixed monthly charges and the usage charges for calling under each option. They find moderate price elasticities of number of calls with respect to usage charges for households subscribing to measured service. Nevertheless, raising usage charges has a negligible effect on revenues, since a sufficient number of households either originally subscribe to flat-rate service or convert to flat-rate service in response to higher usage charges. High elasticity of demand for each service option with respect to its fixed monthly fee indicates high substitutability among service options.

3.7 Summary

The papers reviewed in this chapter show the versatility of discrete choice models in representing consumer choices. In this research, I apply the logic of discrete choice models to firms' choices of locations for customer service representatives. In order to account for flexible substitution patterns and random tastes, I specify the model as a choice model with random coefficients. The next chapter describes the domain and the model for this study.

4 Study Domain and Mathematical Model

The previous discussion has shown the usefulness of discrete choice models in analyzing the demand systems of differentiated product markets. In this research I adopt and extend the framework to firms' hiring and location choices among differentiated regions. Firms choose where to locate their employees based on the characteristics of the region and their own characteristics. Given this framework, the relationship between the importance of regional characteristics and IT investments can then be examined.

4.1 The Domain

As shown in previous productivity studies, there are significant advantages to studying IT effects at the firm level whenever possible. For instance, firm-level data analysis has unveiled the impact of IT on productivity where aggregate-level analysis had only found a productivity "paradox" (Brynjolfsson and Hitt, 2003). Even more insightful are studies of a specific function or process across firms. Narrowing the research domain to a specific well-defined process increases the confidence one has in the accuracy of the econometric results (Ichniowski and Shaw, 2003). For this reason, I focus on manufacturing firms and on one service, archetypical of information work: customer service representatives (CSR) answering customer calls. This type of service consists in providing information to customers on the phone, including processing orders and providing solutions to common questions and inquiries. It is also a good example of a footloose process that in principle can be sited anywhere. This makes it an ideal candidate to investigate in order to gain an understanding of how information technologies may impact the location of information work. I analyze the choices of firms in locating customer service representatives across various US geographical locations. Firms choose where to locate their CSRs (the analogue to consumers choosing which products to buy in a differentiated product setting) and how many CSRs to hire at each location (how many units of each product to purchase).

In addition to providing a restricted domain in which decisions about hiring and location of work can be analyzed, focusing on phone-based customer service has an additional advantage. Telephone call centers are an integral part of many businesses and their economic role is significant and growing. Moreover, the management literature in operations research has studied the interaction between system design (such as the number of employees answering calls) and system performance. Models are inherently simplifications of the operations of the real world but they provide more accurate representations of the way variables in a system interact than the usual linear specification of utility function in traditional models of consumer choice. In the following, I describe the model used to derive the profit of a telephone-based customer service function at a firm.

At the core of the model is a view of customer service as comprised of two related stochastic processes: the arrival process, whereby calls generated randomly by customers reach one of the CSRs at the company, and the service process which corresponds to the time and effort that the CSR puts into answering a call. Call arrivals are unpredictable and vary over time. Likewise, service time is also a non-deterministic function of a variety of control variables. In planning capacity, managers take into consideration whether hiring an additional CSR will improve performance at the firm. In doing so, they need to define a performance measure and examine the marginal benefits and costs of hiring an additional CSR. One such measure, accessibility, is the operational performance related to measurable output such as the time customers have to wait to speak to an agent or the number of customers who abandoned the queue before being serviced. Typically, service operations aim to maximize accessibility net of hiring costs. In my model, I directly relate accessibility to revenue by drawing on the observation that customers whose waiting time is too long are likely to abandon the queue (Mandelbaum et al. (2002) present empirical evidence on the relationship between waiting times and queue abandonment). Lost customers translate into a loss of future revenue stream. Equivalently, higher levels of accessibility are associated with higher net present value of revenue.

It should be noted that alternative revenue measures could also be used. Service quality can be assessed on the basis of the effectiveness of service, or how "well" a call has been answered. This measure parallels the notion of rework in the manufacturing literature and is typically measured by sampling inspection. Similarly, the content of the CSRs' interactions with customers (whether or not the CSR was polite, friendly etc…) is often monitored. Both measures are harder to integrate into a capacity-management model and I do not consider them any further. It is clear however that these types of measures play a role in hiring and allocation decisions of customer service representatives at some companies.

4.2 The Model

Consider a model in which a single type of calls is handled by a number of CSRs at a firm. The arrival process records the times at which calls arrive to the firm. Arrival rates depend on many factors – day of the week, marketing and advertising operations etc... Classical theoretical models posit that arrivals form a Poisson process, which can be justified with the following behavioral argument. Suppose that there exist many potential, statistically identical callers and that there is a non-zero small probability of each one of them calling the firm. In the case of a manufacturing firm for instance, each purchased product may have a (hopefully small) independent probability of a defect and each customer will call the firm given a defect with some probability p. This implies that callers decide to call the firm independently of each other and as a consequence, the aggregate number of calls to the firm can be shown to follow a Poisson process. It is important to realize that forecasts of arrival rates are necessarily inexact and a rough approximation of the real arrival rate. The important point though is not whether arrival rates are an accurate representation of the stochastic process but rather whether they adequately capture the arrival variables that enter the decision process of the decision makers at the firm. The assumption in this model is that they do. Moreover, Mandelbaum (2000) shows that the Poisson distribution is a good approximation of the actual distribution of calls in a call center context.

The firm chooses where to locate its CSRs. However, I assume that the locations are pooled together in providing service. In other words, calls are dispatched to any of the CSRs that are available firm-wide. This is commonly achieved through the use of networking technologies that "virtually" pool together geographically dispersed service centers and allow calls to be routed to different sites. The routing can be based on some priority (hierarchical) scheme. The reason firms may still want to locate CSRs at many different sites is that the characteristics of the location may influence the overall service that the agents at that site provide. For instance, agents physically close to the rest of the firm's activities may benefit from this proximity. The service rate of these agents will then be higher than that of other agents located at other sites, ceteris paribus. On the other hand, it is also possible that proximity has no bearing on the agent's productivity. Perhaps economies of scale associated with large suburban call centers are much more important in driving regional productivity differences. In order to capture potential regional effects, the model allows the service rate to vary across regions.

Capturing proximity benefits through higher service rates is not as restrictive as it may seem. First, the profit function from customer care is directly related to the quality of service provided by the firm. In a queueing model, firms influence QOS by hiring more workers. The model presented here allows the productivity of each additional worker to depend on the benefits of proximity. It is therefore a richer specification than a typical queueing process. Second, additional dimensions of service quality can be conceptually related to higher service rates. For instance, a worker who provides a more accurate answer to a customer inquiry is servicing both the current customer and future calls that this customer would have placed had the answer to her inquiry been less accurate. In operational terms, the service rate has increased.

The most frequently used parametric model of service is that of exponentially distributed durations. The justification for its use can be found in a series of empirical studies that compared empirical distributions of service durations to exponential distributions and found an acceptable fit. Kort (1983) summarized models of the Bell System Public Switched Telephone Network, developed in the 70s and 80s. Harris et al. (1987) analyzed IRS call centers. Both found the exponential distribution to be an acceptable approximation for the distribution of the service duration.

In summary, the two basic building blocks of the stochastic model that describes customer service at the firm are the call arrivals and the customer service provided by CSRs. Arrivals at the firm follow a Poisson process with mean λ_f that depends on the characteristics of the firm D_f. Service times are distributed exponentially with parameter λ_f. The combination of these two processes characterizes the stochastic environment of the model.

Given these processes, I can specify the profit function of providing customer service for the firm. The profit function plays the role of the utility function in classic discrete choice models, but unlike many of these models in which the utility function is a simple arbitrary linear form of the product characteristics, the functional form of the profit function is derived directly from the primitive components of the stochastic queueing model outlined above. Using a queueing model to specify the profit function allows me to provide an approximation of the marginal value of hiring an additional worker in a specific location. Clearly, the marginal value of an additional worker is a function of the number of workers already hired at the firm, and the total number of calls that the firm receives. The queueing model incorporates both the call arrival process and the service process to derive a profit function whose characteristics are more realistic than a simple linear utility function.

Recall that calls arriving at the firm are routed to one of the available agents (regardless of location) or are placed in the queue, waiting for the next available agent. Given a firm's staffing strategy and system load, callers may have to wait in line for the next available agent a long time, and some will drop. Negative impact on customer satisfaction that results from long waiting times and its counterpart, higher satisfaction that results from long waiting times and its counterpart, higher retention rates from quick and efficient service, define a measure of revenue from customer service, R_f. I assume that a call that drops is a loss in revenue. Firm f then chooses the number of agents X_i^f and their locations i to minimize staffing costs and revenue loss from dropped calls.

$$\pi_f = R_f - \sum_i X_i^f P_i \qquad (5)$$

where i is indexing the different regions where the firm locates its CSRs, X_i^f is the choice variable (number of CSRs in region i) and P_i is the unit costs of locating a CSR in region i.

The revenue function R_f can be given an explicit form by using the Pollaczek-Khinchin formula (Gallagher, 1996) that relates, in an M/G/1 queue, the expected queueing time for a calling customer to the expected service time. An M/G/1 queue is a lower-bound approximation of an M/G/n queue (in other words, n servers in parallel can be approximated as one server with a service rate bounded from above by the sum of the service time of the individual servers. In the derivation of the profit function below, I will approximate this compounded service time by a concave polynomial whose order α will be estimated). Specifically the Pollaczek-Khinchin formula implies:

$$\overline{W} = \frac{\lambda E[Z^2]}{2(1 - \lambda E[Z])} \qquad (6)$$

in which $\overline{W}$ is the time average waiting time and Z is customer service time. The customer service time is a function of the number of service representatives and their characteristics. The firm's valuation of the region's CSRs is denoted μ_{if}. As explained above, the relative importance of the regional characteristics V_i enter the model through the marginal value of a CSR in different location, namely μ_{if}, which incorporates the interactions between firm and region characteristics (the $X_i\beta_f$ in Berry, 1994) and is defined as:

$$\mu_{if} = \max(0, \beta_f \cdot V_i)^{m(D_f)} \qquad (7)$$

where β is the marginal value of the regional characteristics V_i to firm f. For instance, firms could value regions differently based on whether or not they already have operations in the region, or whether there is a good fit between the region's characteristics and the production process of the firm. The term $m(D_f)$ is a function of the firm characteristics D_f that captures a form of vertical differentiation between firms in the sense that firms with similar value for the benefits of the region might still differ in their willingness to pay for this regional "quality."

Consider now what happens when a customer does not receive adequate service and its revenue is lost. Suppose that *(1-N)* is the proportion of incoming calls that are not answered (or that are given inadequate service). Then, the average revenue for the firm is $R_f = N^*\lambda_f$. Notice that N, the proportion of incoming calls that do not drop, corresponds to the survival rate of the queueing system. Mandelbaum et al. (2000) study these survival rates and show that they are exponentially decreasing functions of the average waiting time. The waiting time can then be approximated as follows:

$$\overline{W} = \frac{\lambda E[Z^2]}{2(1-\lambda E[Z])} \cong \frac{\lambda\left(\frac{1}{\sum X_i^\alpha \mu_i}\right)^2}{2\left(-\ln\left(\frac{\lambda}{\sum X_i^\alpha \mu_i}\right)\right)}$$

$$= 2\left[\frac{\ln\lambda}{\lambda\left(\frac{1}{\sum X_i^\alpha \mu_i}\right)^2} + \frac{\left(\sum X_i^\alpha \mu_i\right)^2 \ln \sum X_i^\alpha \mu_i}{\lambda}\right]^{-1}$$

$$\approx \left[\frac{2\left(\sum X_i^\alpha \mu_i\right)^2}{\lambda / \ln\lambda}\right]^{-1}$$

Then the survival rate is: $e^{-\frac{\bar{\lambda}}{2(\Sigma X_i^{\alpha}\mu_i)^2}}$ and the associated expected revenue is $R = \lambda e^{-\frac{\bar{\lambda}}{2(\Sigma X_i^{\alpha}\mu_i)^2}}$ where $\bar{\lambda}$ is (ln λ)/ λ.

Firms choose the number of CSRs at different locations in order to maximize the profit function in (5). This problem is a discrete (integer) problem and therefore cannot be solved by standard optimization techniques. It is instructive though, and ultimately useful for solving the maximization problem, to temporarily ignore the integer constraint and derive the optimal number of agents in the relaxed problem. Without the integer constraints, the profit function is maximized at the values for the CSRs that satisfy the first-order conditions. Specifically:

The FOC of the profit function with respect to X_i are:

$$\lambda e^{-\frac{\lambda}{2(\Sigma X_i^{\alpha}\mu_i)^2}}\left(\frac{\lambda}{\left(\sum \mu_i X_i^{\alpha}\right)^2}\right)\alpha\mu_i X_i^{\alpha-1} - P_i = 0 \quad \forall i ,$$

which implies that:

$$\frac{X_i}{X_j} = \left(\frac{P_i}{P_j}\frac{\mu_j}{\mu_i}\right)^{\frac{1}{\alpha-1}} = \left[\left(\frac{\mu_i}{P_i}\right)\Big/\left(\frac{\mu_j}{P_j}\right)\right]^{\frac{1}{1-\alpha}} \tag{8}$$

This derivation yields two interesting insights. First, the relative number of agents between different locations *i* and *j* is given by Equation (8) that shows how a firm's relative valuation of different regions can outweigh cost differentials (so that firms do not necessarily locate in lower cost regions). Equation (8) also shows the factors that affect the importance of non-pecuniary variables (as reflected in the μ's) versus local unit costs (the P's). Firms can prefer higher-cost regions for two reasons: the first reason is that the firm's marginal value of some regional attribute is large and one region is well-endowed in this attribute relative to another region. Alternatively, it may be the case that the value differential between the two regions is small but that one firm's own characteristics (such as high IT intensity) allows it to take advantage of this differential (which another firm is unable to exploit). Firms whose marginal value of regional characteristics is the same but whose own characteristics (as reflected in the term $m(D_f)$) differ may therefore have very different localization strategies.

Second, the derivation of the optimal number of agents in the relaxed problem suggests an approach for solving the integer problem. I can derive the optimal number of CSRs without the integer constraint. For each firm, I select one region (without loss of generality, I select the region i where the firm located the highest number of CSRs X_{if}) and use (8) to compute the ratios of X_{jf}/X_{if} for the remaining regions j. This provides an analytical expression for each X as a function of X_{if}. I then use the first-order condition of the profit function with respect to X_{if} to derive a closed-form solution for X_{if}, and therefore for all the X_{if}. Using this non-integer solution, I search for the optimal vector of integers by means of a standard branch-and-bound algorithm.

For most firms, the procedure is fast enough for the limited number of regions in the sample (see the sample description below) and discovers the optimal integer solution. In the few cases where the optimal integer solution is not found after a number of search iterations, the best integer solution in the branch-and-bound iterations is retrieved (in practice, the variations in the optimal value around the various solutions are minuscule and the error from the approximation is not significant). The outcome of this procedure is a vector X^c of predicted CSR employment in every one of the different regions in the choice set for a given set of random coefficients and parameters.

4.3 Summary

This chapter has derived an expression for the profit function from customer service at a firm building on a stochastic specification of call arrivals and service time. The next chapter will describe the data used in estimating the model and explain how the model presented here and the data are pulled together in estimating the parameters. The results will be discussed in Chapter 6.

5 Data and Estimation

The data used in this research consist of two distinct data sets: One set contains information about firms while the other contains information on region-specific economic variables. The following describes each of these datasets.

5.1 Firm-Level Data

The firm-level data consist of a sample of Fortune 1000 firms in the manufacturing sector (five different SIC 2-digit codes corresponding to industries such as machinery, computer and electric/electronic equipment, food and chemicals). In choosing the industries, care was given to select industries that offered relatively homogeneous customer-support activities (all are manufacturing firms and offer sales and post-sales support of consumer or industrial goods). In addition, the large scale of the firms guarantee that they would produce for a national market and not be tied to local demand and supply factors. This is important because it is difficult to obtain accurate measures of local supply and demand (and by extension the amount of customer service required locally). I removed firms for which data regarding the number of CSRs appeared to be missing or noisy. The total number of Fortune 1000 firms in these four SIC codes is 104.

Table 1 below shows the five SIC codes that were chosen together with the number of firms in the sample in each category. Appendix A lists the 104 companies in the sample.

SIC 2-digit class	SIC Description	Corporations in Sample
20	Manufacturing: Food products	10
28	Manufacturing: Chemicals	26
35	Manufacturing: Machinery	35
36	Manufacturing: Electrical Equipment	20
38	Manufacturing: Instruments	13

Table 1: Industries

The firm sample is constructed using data from Harte Hanks Market Intelligence CI Technology database (hereafter CI database), a database compiled by Harte Hanks Market Intelligence. Harte Hanks Market Intelligence is a commercial market research firm that tracks use of Internet technology in business every year. I use the data collected by Harte Hanks for the year 2000. The CI database contains firm-level data and establishment-level data that include establishment characteristics, such as number of employees, industry and location, use of technology hardware and software, such as computers, networking equipment, printers and other office equipment; and use of Internet applications and other networking services. Harte Hanks collects this information to resell as a tool for the marketing divisions of technology companies. Interview teams survey establishments throughout the calendar year. The sample that I use contains the most current information as of December 2000.

In Table 2, I show a few features of the sample. The largest firm in the sample has 316,303 employees (IBM corporation) which is also the largest firm in terms of sales with 88B dollars of revenue. Ninety eight percent of establishments are part of a multi-establishment firm. The median firm in our sample has 142,690 employees.

Variable	Obs	Mean	Stdv	Minimum	Maximum
Number of Employees (1000's)	104	37.96	43.94	1.95	316.3
Total Sales (in billions)	104	9.7	13.14	1.23	88.4
Number of locations with CSRs	104	3.2	3.7	1	12
Number of locations with CSRs vs total number of locations	104	0.32	0.51	0.09	0.76
Total Number of CSRs	104	129	352	16	2000

Table 2: Sample statistics

For each firm, the data include the firm's annual sales (to control for scale) and its main sector of activity (SIC 2-digit industry). Table 2 also shows the distribution of CSRs across sites at the firms (a single firm has several sites across the US). The table presents statistics of the total number of sites, for each firm, where the firm uses CSRs, the proportion of "CSR sites" (establishments with at least one CSR) relative to the total number of establishments at the firm, and the total number of CSRs at the firm.

In addition to data at the firm level, I also use data at the establishment level that allow me to compute three additional firm-level metrics. The first metric is a measure of diversification, namely the number of sectors (SIC 4-digit codes) in which a firm operates. Customer service at firms that are more diversified may differ from customer service at firms whose operations are more homogeneous. Diversification may restrict a firm's ability to leverage call agents across product lines (or services) and increase the importance of coordination between products or services. In such a case, we would expect firms that are more diversified to be less sensitive to cost differences across regions.

The second metric is the IT variable. The variable reflects both the intensity of Internet usage at the firm and the variety of Internet usage. Variety is important as it captures aspects of how IT is being used in an organization and not solely how much IT the organization invested in. Organizations that tailor technological investments to their organizational needs will be more likely to use a variety of technologies, adapted to the particular circumstances in which different business activities take place. I calculated the IT variable for each firm by aggregating the number of different types of Internet applications used at the sites that employ CSRs. If n is the number of application types used at site i, E_i the number of employees at the site and X_n is the number of applications of type n used at the site, then the value of the IT variable is:

$$IT = \frac{1}{i}\sum_i ((E_i)^{-1/2} \sum_n (X_n)^{1/2})^2 \qquad (9)$$

This metric captures both the intensity of Internet usage at the firm and the variety of Internet usage. Therefore higher values of IT result either from a relatively higher usage of IT at the site, or from a more diverse use of Internet applications. Internet applications encompass what Harte-Hanks code as Internet server applications, Internet applications, Internet/Web programming languages, Internet/Web servers, and Internet/Web software. Examples of these applications are "ecommerce," "technical support," "web development," "Java" and "Web server application."

The last variable is an organizational variable to assess the degree of decentralization at the firm. The decision-rights measure is the proportion of sites for which IT (PCs, non-PCs, and telecommunication) purchasing decisions are made locally (computer purchase decisions are either made locally or at the parent/headquarters). For each site, each one of these decisions is coded as 1 if the purchasing decision is decentralized and 0 otherwise. Aggregating across sites and decisions yields a measure of decentralization at the firm.

Table 3 shows statistics for the three variables, Segments, IT, and Decentralization.

Variable	**Number of Observations**	**Mean**	**Min**	**Max**
G: Segments	104	39.2	1	266
IT: IT variable	104	1.05	0.02	6.54
D:Decentralization	104	0.47	0.13	1

Table 3: Sample statistics for the establishment-level data

5.2 Regional-Level Data

The choice set consists of 92 metropolitan statistical areas (or "regions") of the continental U.S (none of the firms in the sample located customer service activities outside these areas and therefore I ignored the remaining metropolitan statistical areas). The definition of an MSA is that used by the Bureau of Labor Statistics. It incorporates a major urban center and the county (or counties) that contains this city, along with any adjacent counties that have at least 50 percent of their population in the urbanized area surrounding the city. Each MSA is characterized by several variables: the monthly unit costs of locating a CSR in the area, telecom infrastructure, density of the labor force in the region, and a measure of proximity-based externalities. The establishment data specify the MSA in which the establishment is located.

Monthly unit costs (**UC**) of hiring a CSR in a specific MSA include monthly wages, obtained from the BLS data on occupations (occupation code 43-4051, "customer service representatives"), and monthly commercial real estate rents in the area, obtained from the Society of Industrial and Office Realtors. The space requirements for a CSR are drawn from trade publications that recommend between 10 and 14 square meter per person. The total unit costs from business rental expenditures are then calculated as ten times the square meter rate in that region. The BLS data are at the metropolitan statistical area level but the commercial real estate data is at a higher level of aggregation (so that a single value of commercial real estate rents corresponds to several MSAs). This introduces some noise in the cost data. However, rent expenditures are small in comparison to wage expenditures (about 6%) so that unaccounted-for variations in rents will only bias the model if there is little variation in wages, which is not the case.

Figure 1 shows the distribution of wages over all MSAs. Note that there is considerable variation in wages across the US. The minimum monthly wage for a CSR is $1337 and the maximum is $3088.

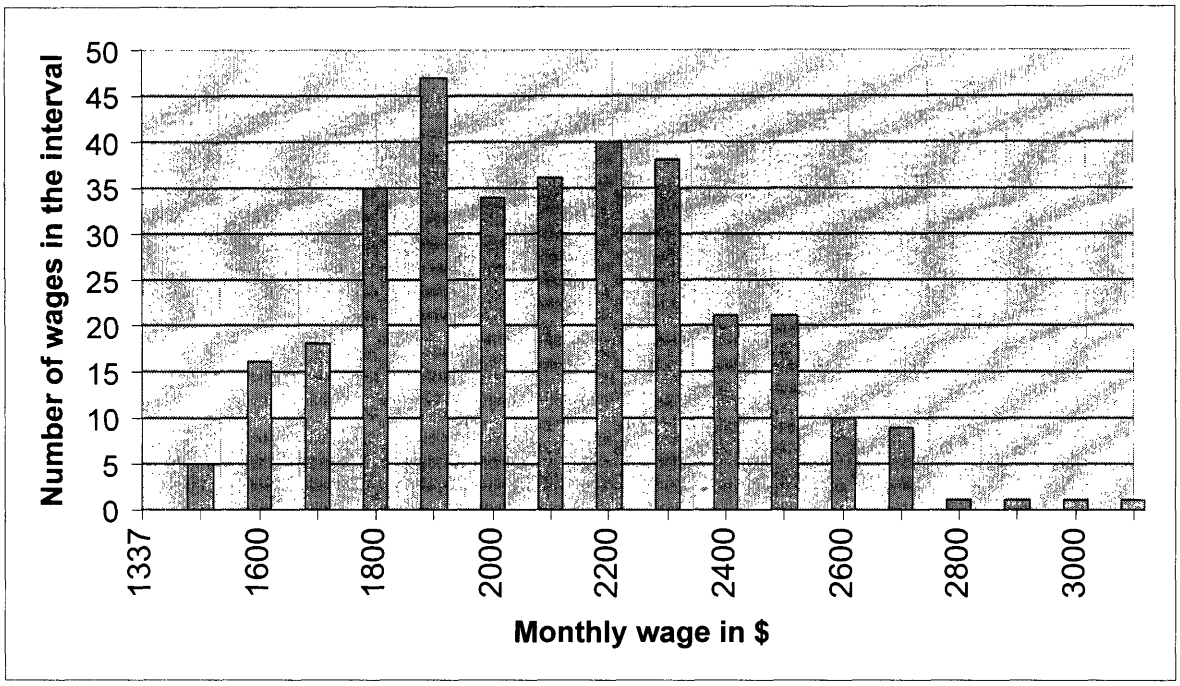

Figure 1: CSR wage distribution across MSAs

The data on telecom infrastructure (**TI**) is intended to capture differences between regions in telecommunication infrastructure. Intuitively, regions for which telecommunication networks are sophisticated (and allow for faster speeds, higher bandwidth and higher reliability) should be attractive to firms that rely on telecommunication for coordinating remote activities. The variable is computed using data from the FCC publication *Statistics of Communication Common Carriers* (2000/2001 Edition) that describe telecommunication facilities of incumbent carriers in different states. I use the ratio of total fiber kilometers deployed (lit and dark) divided by sheath kilometers of metallic cable. Such a measure cancels scale effects (the total amount of cable – metallic or fiber – in one area is correlated with the density of the area) and emphasizes the differences in technology between regions. The data from the FCC are at the state level. Metropolitan-area estimates are generated by setting the MSA estimate to the value of telecom infrastructure of the state to which the MSA belongs.

The third regional variable that I consider is a measure of the available labor pool in the MSA (**LP**). A large labor pool can reduce the initial and subsequent costs of assembling and maintaining a workforce for firms and therefore influence their location and hiring decisions. It is possible that especially for larger firms such as those in the sample an area with a large labor pool might be more attractive. As a proxy for the available labor pool in the MSA I use the number of unemployed individuals in the MSA divided by total unemployment across all MSA. The data are taken from the BLS 2000 Metropolitan Area Employment and Unemployment report.

The proximity variable is designed to capture differences between regions that arise from localized spillovers. More specifically, firms may locate customer service functions close to industrial (manufacturing) centers if they benefit from geographically localized spillovers. As explained above, these externalities arise from many sources including knowledge spillovers. The variable **LS** captures the region's share of manufacturing in the five industries under consideration. It is calculated as the regional share in the five manufacturing industries in the sample (as a share of total manufacturing output of these industries in the country).

Descriptive statistics for the regional variables can be found in Table 4.

Variable	**Observations**	**Mean**	**Std Dev**	**Min**	**Max**
Unit Costs (UC)	92	2192	278	1337	3088
Telecom Infrastructure (TI)	92	0.34	0.54	0.16	0.97
Percentage of Available Labor Pool (LP)	92	0.11	0.19	0.04	0.27
Localized Spillovers (LS)	92	0.08	0.09	0.02	0.18

Table 4: Regional-level Variables

Although these four variables capture many of the regional factors that influence firms' location and hiring decisions, there may be additional regional variables that are not included and may be relevant. For instance, firms may consider the time zone of a location when deciding where to site customer service functions: achieving customer service that is geographically spread across different time zones may be a consideration in deciding where to locate workers. Similarly, tax regimes can influence location decisions. I control for any variable that influences location decisions at the state level by including dummy variables S_j for the states in which firms locate. Therefore, although I am not able to distinguish between state-level factors that influence location decision, the dummy variables account for variations that arise from any state-level omitted variable.

I now combine the model described in chapter 4 and the data presented in this chapter in order to estimate the parameters of the model. The estimation is based on the method of moments in which the integral in (2) is simulated.

5.3 Estimation

The model described above predicts the number of agents $X_f(D_f, \beta_f, \theta)$ at each location for a firm f as a function of observed firm characteristics D_f, random coefficients β_f, and the vector of parameters to be estimated θ. In other words, given β_f and θ the number of agents is a deterministic function of the firm characteristics.

Let $X_f(D_f, \beta_f, \theta) = (X_f^1, ..., X_f^j)$ be the vector of CSRs at firm f and locations $1 ... j$. Since the coefficients β_f are distributed with density $h(\beta|\theta)$ where θ refers collectively to the parameters of this distribution (such as the means and the covariance matrix of β) the expectation of $X_f(D_f, \beta_f, \theta)$, X_f^e (in which the superscript e on X to denote expectation is simply a more convenient notation than the typical expectation operator E) is given by:

$$X_f^e(D_f,\theta)=\int_{-\infty}^{\infty}X_f(D_f,\beta_f,\theta)h(d\beta_f\mid D_f,\theta) \qquad (10)$$

where h is the density of the random parameters β_f conditional on the information D_f. Unfortunately, it is impossible to solve this integral analytically or even numerically as both the regions of integration that generate the different choices and the dimensionality of the integral preclude any kind of closed-form expression for this integral. Nevertheless, it can be approximated through simulation for any given value of the parameters. The procedure is as follows:

(1) Draw a value of β from $h(\beta|\theta)$ and label it β_f^r with the superscript $r=1$ referring to the first draw

(2) Calculate the optimal vector of CSRs, $X_f(D_f,\beta_f^r,\theta)$ with this draw

(3) Repeat steps (1) and (2) R times, averaging the results. This average is the simulated optimal vector of CSRs:

$$\hat{X}_f=\frac{1}{R}\sum_{r=1}^{R}X_f(D_f,\beta_f^r,\theta)$$

$\hat{X}_f$ is an unbiased estimator of X_f by construction. Its variance decreases as R increases. The simulated vector of CSRs is used to estimate the parameters of the model (including the parameters of the distributions) via the method of simulated moments as follows.

Given the predicted staff assignments $X_f^e(D_f,\theta)$ and the observed number of agents X_f at the different locations for firm f, let us define the prediction error $\varepsilon_f(D_f,\theta)$ as:

$$\varepsilon_f(D_f,\theta) = X_f - X_f^e(D_f,\theta) \qquad (8)$$

At the true parameter θ_0, the moment of the prediction error is identically zero:

$$E(\varepsilon_f \mid D_f,\theta_0) = 0 \quad \textit{for } f = 1,\ldots,F \qquad (9)$$

Any function $g(D_f)$ of the conditioning variables must also be uncorrelated with this error. As a result, the value of θ, say $\hat{\theta}$, that sets the sample analog of this moment

$$G_F(\theta) = \frac{1}{F}\sum_1^F g(D_f) \otimes \varepsilon_f(D_f,\theta) \quad (10)$$

equal to zero or as close as possible to zero is a consistent estimator of θ_0. Under appropriate regularity conditions, asymptotic normality of $\hat{\theta}$ is ensured (see Hansen, 1982). If the number of moment conditions is larger than the number of parameters to be estimated (the model is over-identified), an efficient estimator is found by combining the moment conditions through a weighing matrix V. The efficient weighing matrix as suggested by Hansen (1982) is

$$V = E((g(D)\varepsilon)(g(D)\varepsilon)') \qquad (11)$$

$\hat{\theta}$ is then asymptotically normally distributed with mean θ_0 and asymptotic variance-covariance matrix

$$\Omega = \left(\left(\frac{\partial G(\theta_0)}{\partial \theta} \right)' V^{-1} \frac{\partial G(\theta_0)}{\partial \theta} \right) \qquad (12)$$

Unfortunately, the function $X_f^e(D_f, \theta)$ is not known analytically. Unlike classic discrete-choice models in which latent variables are simple linear functions of characteristics and error terms are assumed to have a specific structure (independent across observations with the extreme value distribution e.g., in the logit specification), the profit function above is highly non-linear and the integrals are not easily computable. When analytic expressions are not available, it is possible to obtain simulation-based estimates of the distributions as suggested by McFadden (1989) and Pakes and Pollard (1989). The straightforward way of simulating the expectation $X_f^e(D_f, \theta)$ is by averaging the underlying random function over a set of random draws. The resulting estimator of $X_f^e(D_f, \theta)$ is trivially an unbiased estimator of the true expectation $X_f^e(D_f, \theta)$. McFadden (1989) and Pakes and Pollard (1989) prove that the MSM estimator that sets the simulated moment as close as possible to zero is typically consistent for finite number of simulation draws (the intuition is that the simulation error averages out over observations as $N \to \infty$). To conduct the simulation, it is therefore enough to draw $F \times S \times K$ normals where K is the number of random coefficients per firm. The resulting values represent the random components of *f*'s preferences.

6 Results

The estimation of the model is based on the method of simulated moments. The first step is to compute the predicted staff assignments across regions from the model of firm behavior by maximizing the profit function above. Given a set of values for the various parameters in the model, the optimal location and hiring choices are established. This in turn determines the value of the function G. The process is then iterated for different values of the parameters. In order to estimate the parameters, we need to make assumptions on the functional form and distribution of the random coefficients. The random coefficients are assumed to be normally distributed with mean and variance to be estimated. Fixed effects are introduced to capture regional factors that affect firms' location choices. I include state dummy variables to capture unobserved factors that vary at the state level. Including dummy variables is also useful in reducing the potential endogeneity biases of the kind studied by Berry (1994) in which prices (unit costs) are correlated with unobserved characteristics (the unobserved quality). By using state dummies and assuming that any endogeneity is at the state level, one does not need the inversion procedure that Berry describes. Dummies affect the mean utility level of the state, but have no effect on the substitution patterns between metropolitan areas (these are driven by the variations in the observed characteristics in each metropolitan area). I use random coefficients on each of the state dummies.

In order to estimate the model, I need to specify functional forms for the various components of the model: the arrival rates, the differentiation coefficient and the regional valuation. The arrival rates vary across firms based on various firm-specific parameters.

In the first specification (model A), the parameter λ is simply a function of IT and $\overline{CSR}$ (the average number of CSRs in the industry in which firm *f* operates). The dependence on IT reflects the possibility that offering web-based customer support reduces the number of calls to the firm. The arrival rate at firm *f* in model A is therefore:

$$\lambda_f^A = \left(f_0 + f_1 * IT_f + f_2 * \overline{CSR}\right) * S$$

The second specification (model B) enriches the functional form of λ by incorporating the diversification variable (G) as well as a dummy variable ND that takes value 1 if the firm's primary industry is an industry that produces non-durable goods.

$$\lambda_f^B = \left(f_0 + f_1 * IT_f + f_2 * \overline{CSR} + f_3 * G_f + f_4 * ND\right) * S$$

The vertical differentiation coefficient, $m(D_f)$, is assumed to be a linear function of two characteristics of the firm, namely IT and decentralization as follows (the intercept is normalized to 1):

$$m(D_f) = 1 + m_1 IT + m_2 D \qquad (13)$$

This functional form allows firms to differ in their relative preferences (between cost and other regional benefits) based on the intensity of their IT investments and the degree of decentralization at the firm. Finally, the characteristics of the region *i* enter the marginal utility of service as follows:

$$\mu_j = \alpha_j + \beta_1 LF + \beta_2 TI + \beta_3 LS + \gamma S_j$$

where S_j is a state dummy variable for region j.

The estimation was performed in Matlab. I increased the number of draws from three (for the first estimation passes) to ten (R=10) in order to increase efficiency (see McFadden, 1989). I computed the predicted vector of CSRs (the vector has ninety two elements, one per region) as explained above in the estimation section. Following McFadden (1989) and Pakes and Pollard (1989), I held the draws constant over different function evaluations (to avoid infinite jumpiness) and used different simulation draws for different observations to make the simulation error average out faster. The instruments that I used were a constant, the number of sectors a firm operates in and the decentralization variable at the firm. The profit function in (5) is non-differentiable for any finite number of simulation draws. Therefore, I used the Nelder-Meade non-derivative "simplex" search algorithm to minimize the function (Hendel, 1999). To ease the search, I broke the problem into two sub-problems, estimating the dummy coefficients and then the other parameters, before estimating the whole coefficient vector. Estimates of the parameters can be found in Table 6 (parameters that are significant are in bold)

	Model A	*Model B*
f_0 *(intersect of arrival rate equation)*	$0.297*10^{-3}$ ($0.311*10^{-3}$)	$0.354*10^{-3}$ ($0.416*10^{-3}$)
f_1 *(IT in arrival rate)*	**$-0.0019*10^{-3}$** ($0.0007*10^{-3}$)	**$-0.0026*10^{-3}$** ($0.0011*10^{-3}$)
f_2 *(Avg number of CSRs in industry in arrival rate)*	**$0.044*10^{-3}$** ($0.013*10^{-3}$)	**$0.092*10^{-3}$** ($0.047*10^{-3}$)
f_3 *(Industry segments in arrival rate)*	-	$-0.136*10^{-5}$ ($0.075*10^{-5}$)
f_4 *(Non-Durable Dummy)*	-	$0.22*10^{-3}$ ($1.04*10^{-3}$)
m_1 *(IT in differentiation coefficient)*	**-0.0068** (0.0018)	**-0.0081** (0.0029)
m_2 *(Decentralization variable in differentiation coefficient)*	-0.094 (0.187)	**-0.021** (0.0106)
$Var(\gamma)$ *(variance of random coeff)*	**10.9** (2.81)	**9.2** (3.5)
β_1 (Labor Pool in the Region)	**0.31** (0.184)	**0.27** (0.12)
β_2 (Telecom Infrastructure)	-0.056 (0.197)	-0.182 (0.333)
β_3 (Proximity Variable)	**0.279** (0.114)	**0.314** (0.148)

Table 6 Parameter Estimates. Bold font indicates statistically significant parameters at the 5% confidence level

The significant f_1, in both models, captures the relationship between Internet applications at the firm and the call volume at the firm. The sign of the coefficient is negative, pointing to a negative relationship between the average number of calls at the locations we observe and the use of Internet applications by the firm. As mentioned above, this could be the result of fewer callers (customers of firms with extensive Internet presence substitute Web-based service to call agents), or to the outsourcing of customer service to locations that we do not observe such as, for instance, overseas. The magnitude of the coefficient shows that there is a small impact of Internet business applications on these practices, even though the data cannot distinguish between the two effects.

The coefficient f_2 which measures the impact of the average number of CSR in each industry on the call volume at the firm is significant at the 5% level and as expected, positive in both models. The two coefficients on diversification and non-durables in model B are not significant.

To evaluate the magnitude of the Internet effect on CSR employment, I use the first-order conditions above to find the elasticity of X with respect to the use of Internet applications. To keep things simple, I assume that the value of $m(D_f)$ stays constant (i.e., there is a compensating change in the decision- rights variable with the change in the IT variable so that $m(D_f)$ remains constant). Given this assumption, the elasticity of X with respect to the use of Internet applications, at the sample means, has a value of -0.13. That is, a 10% increase in the index of Internet application use is associated with a 1.3% decrease in the national employment of CSRs. Alternatively, a doubling of the index of Internet application decreases employment by 13%.

The coefficients m_1 and m_2 are significant in model B although m_2, the coefficient on decentralization is not significant in model A. When significant, they support the hypothesis that Internet usage and decision rights affect location choice patterns. The coefficients are negative, suggesting that firms with higher Internet usage, or more dispersed decision rights, are less sensitive to quality differences between regions and more cost-sensitive. In other words, Internet-based applications and distributed decision rights reduce the vertical differentiation with respect to non-pecuniary regional benefits between firms. To get a sense of the magnitude of these effects, I calculated the change in average costs from a change in $m(D_f)$. Given a valuation ratio k_i (between a region i and a reference region j), the elasticity of relative regional employment (between i and j) with respect to m_1 is $\varepsilon_i = m_1 * ln\ k_i * IT$. The change in total costs TC'/TC is then:

$$\frac{TC'}{TC} = \frac{\sum_i \varepsilon_i k_i P_i}{\sum_i k_i P_i} \qquad (14)$$

Evaluated at the regional dummy coefficients (the mean utility of the different regions) and sample mean of IT, the change in total costs is equal to -0.098 (using the estimated value of model B). Thus, a 10% increase in the number of Internet applications (per sales) is associated with savings of about 1% from the unit costs of CSRs. The intuition behind this result is that firms take advantage of lower unit costs by locating their staff in regions that would not have been attractive without IT, presumably because of coordination and informational costs. The same technique gives an estimate of the impact of a change in decision rights allocation between subsidiaries and headquarters (replace $m1$ by $m2$ and IT by D in ε_i). The resulting value is -0.02, which implies that increasing the number of sites to which purchasing decision rights are delegated (or the number of decisions delegated to a branch) by 10% results in a 0.2% reduction in unit costs from relocation. In other words, firms that are more decentralized are more likely to take advantage of cost arbitrage between regions and save on unit costs. An interesting result concerns the coefficient Var(γ): it is significantly different from zero, indicating heterogeneity in tastes among firms between regions. This result validates the use of random coefficients for regional dummies, and shows that idiosyncratic differences among firms have a significant impact on valuation of regions, and ultimately, location decisions.

The individual effect of regional characteristics on valuation is reflected in the coefficients β. The coefficient on TI (telecom infrastructure) is of the wrong sign, with large standard error. This might be a result of poor data, the FCC data being an aggregated index that covers the infrastructure of residential, rural, and business telecommunication lines and is perhaps not sufficiently correlated with the portfolio and price of telecom services offered to businesses. Also, since local residential markets have not become as competitive as business and long-distance markets, the index might not reflect true telecom costs for businesses. Finally there has been over-investment in fiber optic lines at the end of the century such that the telecommunication infrastructure differences between regions have become less critical to firms (since all regions offered similar technological capabilities). But it could also be that regional telecom infrastructure is not a significant factor influencing firms' location decisions. Both of the variables that capture externalities due to proximity (to other firms or to the firm's own activities) are however highly significant. This shows that firms value proximity to their own activities and proximity to other firms or to customers. Finally, the density of the labor force (LF) has the expected sign and is significant at the 10% confidence level in one model specification but not in the other. It suggests that firms may value proximity to regions where the labor pool is large. The R^2 of this regression is 0.17, suggesting that random valuation accounts for most of the variation in regional preferences.

6.1 Discussion

The results above suggest that IT has an impact on a firm's ability to de-locate activities and reduces its dependence on location-related characteristics. Specifically, I found that:

1. As a firm uses more IT, its ability to exploit cost differentials increases. In other words, lower-cost locations are more attractive to IT-intensive firms. This translates into cost savings of about 1% of total unit costs for every 10% increase in IT.

2. The elasticity of CSR employment to the use of IT is -0.13. There are two possible explanations for this finding. First, technology may substitute for domestic representatives. UPS for instance delivers packages and documents throughout the United States and in over 200 other countries and territories. It has installed information systems that allow customers to track their packages through the Internet. In 2003, UPS delivered an average of more than 13 million pieces per day worldwide. Assuming that only 1% of these packages were tracked by customers (a conservative assumption), 130,000 calls to customer service representatives are saved by using the Internet. Clearly, the Internet substitutes for CSRs in this case. It is also possible that technology makes employees more efficient. Verizon for instance uses an Internet-based customer support system that allows a customer to "chat" online with a representative by opening a window called a "ticket." This allows CSRs to be more efficient by enabling them to deal with several customers at the same time. Both of these reasons could explain the substitution effect found in the data.

3. Mean regional preferences vary significantly between firms, even after accounting for characteristics of the area. This suggests that the idiosyncratic factors that enter firms' location decisions are non-negligible. Still regional characteristics help explain preferences: location externalities (the benefits of proximity to customers, other firms or other activities at the same firm) explain part of the firm-specific regional preferences. Region-specific characteristics however, such as labor markets and telecom infrastructure cannot be shown to influence location decisions based on this dataset.

4. I also found that sensitivity to location characteristics is lower the more decentralized the firm is. Presumably, firms whose decision loci are decentralized may be able to take advantage of regional cost differentials by delegating authority to the division managers. The next chapter will consider a model of delegation of decision rights from headquarters to divisions and the implications for investment in compatibility. It must be noted though that the finding does not imply any causality: in fact, it is quite possible that firms who delegate decision rights are those whose dependency on locational externalities is weak in the first place, which then explains why they are also more likely to benefit from the substitution between IT and these location benefits.

6.2 Assumptions, Limitations and Possible Biases

The IT construct incorporates variety in use of IT. As such, this construct may capture spurious correlation with other sources of variety at the firm (e.g., product diversification). In order to control for variety, I used the "industry segments" variable G in the specification of $m(D_f)$ as followed:

$$m(D_f) = m_1 IT_f + m_2 R_f + m_3 G$$

The results are reported in Table 7. The estimated parameters do not change significantly from the inclusion of the "industry segments" variable. The coefficient on this variable itself is not statistically significant and of the wrong sign.

Another potential source of bias arises from the fact that the data are collected by Harte-Hanks through a survey of firms. This can potentially introduce a bias if the firms that reported data on their CSRs are systematically more likely to be IT-intensive. In order to test whether the sample of firms reporting data for CSR employment was significantly different from those that did not report, I performed a t-test of the means of IT between the two samples. The t-test rejected the hypothesis of different means, so that sampling bias did not appear to be an issue in the sample.

	Model A	*Model B*
f_0 *(intersect of arrival rate equation)*	$0.234*10^{-3}$ ($0.306*10^{-3}$)	$0.524*10^{-3}$ ($0.611*10^{-3}$)
f_1 *(IT in arrival rate)*	**$-0.0037*10^{-3}$** ($0.0009*10^{-3}$)	**$-0.0041*10^{-3}$** ($0.0019*10^{-3}$)
f_2 *(Avg number of CSRs in industry in arrival rate)*	**$0.061*10^{-3}$** ($0.014*10^{-3}$)	**$0.087*10^{-3}$** ($0.0417*10^{-3}$)
f_3 *(Industry segments in arrival rate)*	-	$-0.111*10^{-5}$ ($0.082*10^{-5}$)
f_4 *(Non-Durable Dummy)*	-	$0.234*10^{-3}$ ($0.49*10^{-3}$)
m_1 *(IT in differentiation coefficient)*	**-0.0066** (0.0014)	**-0.0081** (0.0026)
m_2 *(Decentralization variable in differentiation coefficient)*	-0.075 (0.136)	-0.015 (0.011)
m_3 *(Industry segments in differentiation coefficient)*	0.0008 (1.23)	0.016 (0.98)
$Var(\gamma)$ *(variance of random coeff)*	**8.32** (1.99)	**9.1** (3.9)
β_1 (Labor Pool in the Region)	**0.37** (0.184)	**0.41** (0.15)
β_2 (Telecom Infrastructure)	-0.011 (0.612)	-0.61 (0.934)
β_3 (Proximity Variable)	**0.67** (0.21)	**0.84** (0.33)

Table 7 Parameter Estimates. Bold font indicates statistically significant parameters at the 5% confidence level

The MSM estimators reported here are consistent if the instruments are uncorrelated with the model residuals. Ultimately, whether the instruments are really uncorrelated with the residuals is an open question. There is however no a priori reason to suspect any correlations between them. Notice also that the estimators are unbiased even for a fixed number of draws as the simulated distribution enters the moment equation linearly. Although MSM estimators are less efficient than MSL (maximum likelihood) estimators, the unbiasedness of the MSM estimators makes MSL estimators would be biased as the simulated distribution is a non-linear function in the likelihood function.

6.3 Sensitivity of the Results to the Specification of the IT Variable

The IT construct used in this study is non-traditional. As explained above, the rationale for using equation (9) above to define the IT intensity at the firm is that it provides a better measure of how IT is actually used at the firm than traditional accounting measures such as IT budget. In addition, there are no readily available financial data of IT investment at the site level so that any metric of IT would have to use aggregate accounting measures such as total IT budget at the firm level. However, one may wonder whether the calibration of the IT metric in (9) to account for the diversity in IT investment by the firm is driving the results. In order to test the sensitivity of the results to the specification of the IT variable, I estimated the model parameters of a modified model A for which the IT construct is defined as:

$$IT = \frac{1}{i}\sum_{i} 1/E_i \sum_{n} (X_n)$$

This specification simply defines IT as the number of Internet applications per employee, without accounting for the diversity in these applications. The results appear in Table 8.

	Model A, modified IT construct
f_0 ***(intersect of arrival rate equation)***	$0.297*10^{-3}$ $(0.311*10^{-3})$
f_1 ***(IT in arrival rate)***	**$-0.0018*10^{-3}$** $(0.001*10^{-3})$
f_2 ***(Avg number of CSRs in industry in arrival rate)***	**$0.045*10^{-3}$** $(0.022*10^{-3})$
m_1 ***(IT in differentiation coefficient)***	**-0.0074** (0.003)
m_2 ***(Decentralization variable in differentiation coefficient)***	-0.124 (0.187)
$Var(\gamma)$ ***(variance of random coeff)***	**12.9** (4.41)
β_1 **(Labor Pool in the Region)**	0.15 (0.094)
β_2 **(Telecom Infrastructure)**	-0.036 (0.097)
β_3 **(Proximity Variable)**	**0.152** (0.065)

Table 8 Parameter Estimates. Bold font indicates statistically significant parameters at the 5% confidence level

The results do not show any significant qualitative change in any of the parameter estimates. The main consequence of changing the IT construct is to increase the standard deviations of the parameter estimates. Also, the estimate for the parameter on the labor force LF becomes statistically insignificant. The conclusion from these results is that including diversity in the IT construct does not capture the differences in IT investment between firms (which are reflected in the total IT applications per employee already) but increases the efficiency of the parameters.

6.4 Managerial Implications

This research suggests several ways for managers to approach the location decisions that are quickly becoming crucial to business operations in an interconnected world. Managers need to understand the right balance between short-term benefits (cost savings) and long-term capabilities. This will entail deciding what functions should stay and what functions can be de-located. The important conclusion of this research is that there exist some location benefits that are responsible for some of the firm's productivity, and that some of these benefits may not be apparent to managers. The productivity advantage that arises from location should be carefully weighed against the potential cost savings from de-location, and care must be taken to replicate the sources of these productivity advantages, if possible, in the new location. Viewed this way, off-shoring bears some similarity to a surgical operation: delicate geographical connections between activities must be preserved if the firm does not want to lose a source of its productivity advantage and IT cannot always replace every one of these interconnections.

6.5 Future Research

Future research will address other industries, and other functions (such as programming for instance). It is possible that the importance of location and the degree of substitutability between IT and location benefits depends on the type of task that is being performed. Future research in that area would shed light on this question. It will also be interesting to look at the performance of the firms that de-locate activities. I have recently undertaken such an analysis. Longer-term, we need to understand what is happening inside firms that makes de-locating activities easier or, on the contrary, impossible.

7 IT and Decentralization

Widespread investments in information technologies have allowed firms to coordinate activities inside the firm by sharing databases, exchanging documents, combining products and in general simply communicating directly across the enterprise. A central requirement of the collaborative process between organizational actors of the firm is for the technology and the assumptions embedded in that technology to be compatible among the interacting agents. While compatibility and standards have had important implications for the suppliers of technology (including decisions on whether to make a product compatible with those of rivals, thereby competing within a standard, or make them incompatible and then competing between standards) the requirement for compatibility across different organizational units within the firm has implications about the structure of the firm. Since the productivity of many information technologies (in particular communication technologies) rely on network effects in which the marginal productivity of the adoption of a technology by one part of the firm is higher if the rest of the firm adopts this technology as well, firms have an incentive to require coordinated investments in technology across the enterprise. Disparate systems entail higher maintenance costs and result in costly communication when different units must collaborate on a given product. Still, research in IS has also highlighted the fact that productivity of computer investments is highly dependent on co-investment in complementary assets (for instance, human capital and work processes). In fact, the last chapter of this thesis reports on a survey of enterprise-wide large IT projects in a sample of firms that demonstrates that hardware investments account for less than a third of the total costs of implementation of large-scale software projects. Many of these additional investments are intangible and highly dependent on the local expertise and the knowledge of the branch or division. In order to generate the best fit between the computer investments and the intangibles, firms choose the parameters of their organizational structure, and in particular the allocation of decision rights, such that the need for compatibility across divisions is balanced with the productivity benefits of accessing local expertise. The necessity to keep computer investments compatible across divisions introduces coordination costs and encourages firms to centralize investment decisions in technologies with strong network effects at the headquarter level so that investments are compatible across divisions. However, when local knowledge is very important, the uninformed headquarters have an incentive to delegate decision rights to the local branch (Jensen and Meckling, 1992). This tradeoff between local knowledge and coordination explains the patterns of decision rights allocation within the firm.

7.1 Literature Review

Standardization and compatibility have long been studied for their impact on the strategic choice of product manufacturers in the computer, telecommunications and consumer electronics industries. New product innovations have the potential to level the field between incumbents and new entrants (Brynjolfsson and Kemerer 1996) by reducing the lock-in that arises from the existing technological base. Compatibility increases consumer welfare in many markets: compatible ATMs increase the availability of bank point-of-contacts (Saloner and Shepard, 1995) for instance and is evident in many markets ranging from game consoles to stereo systems. Compatibility is not limited to technological product markets. Puffert (1991) discusses compatibility in the context of railway gauge standardization in the southern US during the mid-nineteenth century. Before standardization, at every break of a gauge (the border between two regions) goods had to be transshipped from one piece of the network to the other resulting in significant costs. This problem led to the conversion of more than 20,000 miles of track in North America alone. Information technologies and the development of the Internet have contributed in moving the standardization and compatibility issues to the frontline as researchers attempted to understand how the economics of network effects can explain the emergence and persistence of dominant players in markets such as operating systems (Microsoft), servers (IBM) and microprocessors (Intel).

The bulk of the research in the area of standardization attempts to explain demand-side scale economies that arise from compatibility in the form of increasing returns to adoption, in which the value a consumer derives from purchasing a good increases with its scope of diffusion. Economides and Flyer (1998) examine two different regimes of intellectual property rights: non proprietary (firms can freely coalesce) versus proprietary standards (each firm has its own technical standard and a consensus is necessary). Equilibria of the two-stage game are often asymmetric in production levels, prices, output, a tendency which increases with the intensity of network externalities. This stream of research is mainly concerned with the industrial organization implications of network effects: they can act as a multiplier on firms' incentives to undercut their rivals (De Palma and Leruth, 1993). The benefits of compatibility can also be indirect: Cusumano et al. (1992) argue that the availability of complementary products (prerecorded tapes) drove VHS to dominate over Betamax in the early 1980s though both technologies were of similar quality. Cottrell and Koput (1998) estimate the effect of software provision on the valuation of hardware in the early microcomputer industry and find a positive relationship between software availability and platform price: variety serves as a signal for platform quality. In Farrell and Saloner (1986) standardization is a constraint on product variety. When consumers have different preferences in their ideal specifications for the good, standardization drives some consumers to purchase their less preferred version of the good in order to attain a larger network benefit; this in turn might yield too little variety compared to the social optimum.

Much of the literature on compatibility considers therefore the question from a market-level point of view: pricing, competition, product choice and market power. There is little research on how compatibility influences the industrial organization of the firm itself, and the empirical research is even scarcer. Greenstein (1993) studies mainframe procurement decisions in government agencies and shows that compatibility with installed base is a major factor affecting purchase decisions. Much of the research on compatibility inside the firm focuses on the importance of switching costs in investment decisions: Breuhan (1997) examines the role of switching costs on firm software purchase decisions and finds switching costs of migrating from Wordperfect to Microsoft Word. Forman and Chen (2004) study the impact of switching costs on vendor choice in the market for routers and switches. While informative with respect to the importance of compatibility in driving investment decisions inside the firm, these studies do not consider the broader issue of how compatibility requirements affect both investment decisions and the internal organization of the firm, in particular its allocation of decision rights.

In this research I propose to study the tradeoff within firms between the need for compatibility and the need to access local knowledge at the sites. I present a model that captures the following two forces pulling in opposite directions: on the one hand, headquarters would like division managers to use their knowledge of the inside workings of their divisions to derive maximum productivity benefits from technology investments. This is because headquarters do not know which investments are most appropriate for the division. On the other hand, managers and headquarters' goals are not completely aligned: headquarters are interested in minimizing incompatible technologies so that coordination across units will be more efficient whereas division managers prefer to maximize the profits of their own divisions even at the expense of the rest of the organization. The next section describes the model in more detail.

7.2 The Model

Consider a model of a firm with two divisions di and dj, both of which are risk-neutral. Both parties must decide on the nature and magnitude of some investment in technology. For technology to be compatible across the two units, di and dj must choose similar technologies. Technological choices by di and dj are fully compatible if both divisions choose the same technology, and the farther away the choice of each division, the less compatible the technologies are. To simplify the model, we assume that party dj has only one use for the technology (inside the relationship with di) while party di uses the investment both inside its relationship with dj and for some other productive activity specific to di. This implies that whereas compatibility is critical to dj, di has another use for the technology (a private use) that does not require compatibility with dj. di must therefore weigh the tradeoffs between the benefits it derives from using the technology in its private use versus in the relationship with dj. Technology usage is non-rival (so that di using the technology in the relationship with dj does not preclude the use of the technology for her private needs).

Both di and dj belong to the same firm with headquarters H. Headquarters decide whether to grant purchasing decision rights to each of the divisions di and dj. If the two divisions choose technologies that are not fully compatible, there is a cost to the company proportional to how incompatible the choices are, with marginal costs rising with the degree of incompatibility. When decision rights are centralized at headquarters, headquarters decide which technology is implemented at each division. Headquarters can also decide to transfer decision rights to one or both divisions. Transferring decision rights to a division d means that d has the right to choose its technology. A division that has the right to choose its technology also bears the full costs of coordination in the event technological choices at the two divisions are not compatible, provided that the other unit did not have the right to choose its technology as well. If decision rights are delegated to both divisions, coordination costs are split evenly between the two units (symmetric splitting of coordination costs also happens if rights are centralized at headquarters).

The degree of interconnection between the two units (a measure of how dependent they are on each other) is denoted by χ. This represents how much of the total output of division d_i is dependent on d_j. χ is assumed to be exogenous and is determined prior to any interaction between the two divisions.

The choice of technology by a division d_k consists in choosing a variable a_k, $k \in \{i, j\}$. In order to achieve perfect compatibility between the two divisions, ai should be set equal to aj. The choice of ai however influences how well the technology is adapted to the local environment of di. The local information that enables di to adapt the technology for her private use is a random variable $\theta i, 0 \leq \theta_i \leq 1$, with mean $\bar{\theta}_i$ and variance σ_i^2. The realized value of θi is observable by di only. In order to achieve the best fit between the technology and the local environment, di should set ai equal to θi.

We are now in a position to specify the production function of the organization as a function of ai, aj, χ and θi:

$$F(ai, aj, \theta i) = \chi\left(1 - (ai - aj)^2\right) + (1 - \chi)\left(1 - (ai - \theta i)^2\right) \qquad (1)$$

The first term in F reflects the need for compatibility between the divisions, while the second term corresponds to di's individual contribution that is independent of dj. To keep things simple, the specification of F implies that only di faces a tradeoff between local fit and global compatibility. Dj's sole concern is to achieve compatibility with di's technological choice. While restrictive, this specification allows me to focus on the tradeoff between local fit and compatibility within one division, without the complications that arise when both divisions face this tradeoff independently. Notice that the maximum output achievable is normalized to 1, and that lack of compatibility (respectively lack of fit) subtracts from the output in proportion to the relative importance of compatibility and fit in the production process. For instance, if di has very little interaction with dj, χ will be low and achieving better fit with local circumstances more crucial than achieving compatibility.

7.3 Optimal Choices under Different Delegation Regimes

I now determine the optimal investment choice by the two divisions under different rights regime. There are four different situations:

1. Technology choice is centralized at headquarters for both decisions (this is the "central planner" outcome).
2. The right to choose the technology is delegated to division di but is centralized for division dj.
3. The right to choose the technology is delegated to division dj but is centralized for division di.
4. Both divisions are delegated the right to choose the technology.

As will be seen below, in this simple model what matters is whether di has decision rights or not. To show this, I consider each of these situations in turn.

7.3.1 Full Centralization

In this case, headquarters maximize (1) by choosing both ai and aj.

$$\langle \hat{a}i, \hat{a}j \rangle = \underset{ai,aj}{\arg\max} \left\{ \chi\left(1-(ai-aj)^2\right) + (1-\chi)\left(1-(ai-\theta i)^2\right) \right\}$$

The first-order conditions yield:

$$\begin{aligned} &E(-2\chi(ai-aj)-2(1-\chi)(ai-\theta i))=0 \\ &E(2\chi(ai-aj))=0 \end{aligned}$$

which implies that $ai = aj = \bar{\theta} i$

Under full centralization, the choice of technology by headquarters for both divisions is based solely on compatibility concerns. Given the lack of knowledge regarding the local circumstances θ_i, headquarters' best strategy is to focus on maximizing compatibility between the two divisions. This is consistent with what we would expect since the comparative advantage of centralization is in headquarters' ability to impose a common environment across the enterprise.

7.3.2 Partial Decentralization: the Case of d_j

In this case, decision rights are delegated to dj but remain centralized for di. Since only one division has decision rights delegated to her, dj bears the full costs of coordination. The division of output is therefore:

$$O(dj) = \chi\left(1-(ai-aj)^2\right)$$

$$O(di) = (1-\chi)\left(1-(ai-\theta i)^2\right)$$

Division dj maximizes output by choosing aj, while headquarters maximize output by choosing ai.

The first-order conditions are:

$$E(-2(1-\chi)(ai-\theta i)) = 0$$
$$E(2\chi(ai-aj)) = 0$$

which imply that $ai = aj = \overline{\theta} i$ as well. In this case, since it is optimal for dj, who has the decision rights, to set her technological investment in order to maximize compatibility, she will have an incentive to emulate the choice of technology of di. But di does not have the decision rights, and therefore her choice of technology is determined by the uninformed headquarters. The optimal setting in that case is for headquarters to set technology at di to be the expected value of her local information and for dj to copy this choice as well.

Notice that in this setting, headquarters are indifferent between delegating decision rights to dj or keeping them all centralized. Indeed, delegating decision rights to dj (but not to di) in a model where dj cares only about compatibility is equivalent to keeping the decision rights centralized. This is not the case however when decision rights are delegated to di as the following shows.

7.3.3 Partial Decentralization: the Case of d_i

In this case, decision rights are delegated to di but remain centralized for dj. As in the case above, since only one division has decision rights delegated to her, di bears the full costs of coordination. The division of output is therefore:

$$O(di) = \chi\left(1-(ai-aj)^2\right)+(1-\chi)\left(1-(ai-\theta i)^2\right)$$

$$O(dj) = K$$

where K is some fixed payment (transfer) from di to dj (which can be zero).

In this case, the marginal product for dj is fixed for any investment aj. Let us assume that headquarters chooses $aj = \overline{\theta}i$, a reasonable assumption since $\overline{\theta}i$ is the most salient value of investment in this problem (similar to "sunspot" refinements of Nash equilibria in the presence of multiple equilibria). Although the qualitative results are not affected by the choice of dj, the analysis is simplified if a particular equilibrium is picked among the possible equilibria.

The interesting side of this situation is in di's choice of a technology. The first-order condition for di given dj's choice is:

$$\begin{aligned} &-2\chi(ai-aj)-2(1-\chi)(ai-\theta i)=0 \\ &\Rightarrow ai = \chi\overline{\theta}i+(1-\chi)\theta i \end{aligned}$$

Therefore, di's choice of a technology reflects the tradeoff between compatibility and local knowledge. di's incentive to choose a technology that will be compatible with the choice that headquarters impose on dj is weighed by her desire to fit the technology to her local circumstances so that she can derive productivity benefits from the better fit. The relative weight that di assigns to each of these concerns depends on the relative importance of dj's inputs in di's production process. If the share of the inputs that dj contributes to di is small, there is a larger incentive for di to neglect compatibility and emphasize local fit.

The last case corresponds to the situation where headquarters delegate decision rights to both firms.

7.3.4 Full Decentralization

In this case, decision rights are delegated to both firms, and both share the costs of incompatibility. The utility function of each division is then:

$$O(dj) = \chi\left(1 - \frac{1}{2}(ai - aj)^2\right)$$

$$O(di) = \chi\left(1 - \frac{1}{2}(ai - aj)^2\right) + (1 - \chi)\left(1 - (ai - \theta i)^2\right)$$

Each division maximizes its output function independently of the other's choice of technology. The first-order conditions are:

$$FOCj : E(\chi(ai - aj)) = 0 \Rightarrow aj = E(ai)$$

$$\begin{aligned}
FOCi : &\ \chi(ai - aj) + 2(1 - \chi)(ai - \theta i) = 0 \\
&\ \chi ai - \chi aj + 2ai - 2\chi ai - 2\theta i + 2\chi\theta i = 0 \\
&\ ai(2 - \chi) = \chi aj + 2\theta i - 2\chi\theta i \\
&\ ai = \frac{\chi aj + 2\theta i(1 - \chi)}{2 - \chi}
\end{aligned}$$

Plugging in the value for aj, we get

$$E(ai) = E\left(\frac{\chi E(ai) + 2\theta i(1-\chi)}{2-\chi}\right)$$
$$\Rightarrow (2-\chi)E(ai) = \chi E(ai) + 2(1-\chi)\bar{\theta} i$$
$$\Rightarrow E(ai) = \bar{\theta} i$$

which in turn determines ai:

$$ai = \frac{\chi\bar{\theta} i + 2\theta i(1-\chi)}{2-\chi}$$

The first observation is that in this case, the optimal choice of technology for dj is also $aj = \bar{\theta} i$ as in the previous cases, although the rationale is different. Whereas in previous cases compatibility was achieved by choosing $aj = \bar{\theta} i$ since headquarters were responsible for choosing ai (and headquarters not being more informed than dj herself about θi would require di to take action $\bar{\theta} i$), one could think that in the case of full decentralization, the best response on the side of dj should take into account the fact that di is now free to choose her technology. But the derivation above shows that the expectation of the choice of di is $\bar{\theta} i$ so that there is little reason for dj to choose another value: dj's "best bet" is still to choose the expected value of di's local information. The second observation is that di's best response is again a weighted average of her desire to achieve compatibility with dj and to obtain the best fit between her technological investment and the local conditions. However, the weights on each component differ from the case of partial decentralization above. Here, di puts $\frac{\chi}{(2-\chi)}$ on the compatibility component of her investment decision and $\frac{2-2\chi}{(2-\chi)}$ on the fit with her local knowledge.

The following graph shows how the relative weights on these components change with χ for the cases of full decentralization and partial decentralization (the case of di).

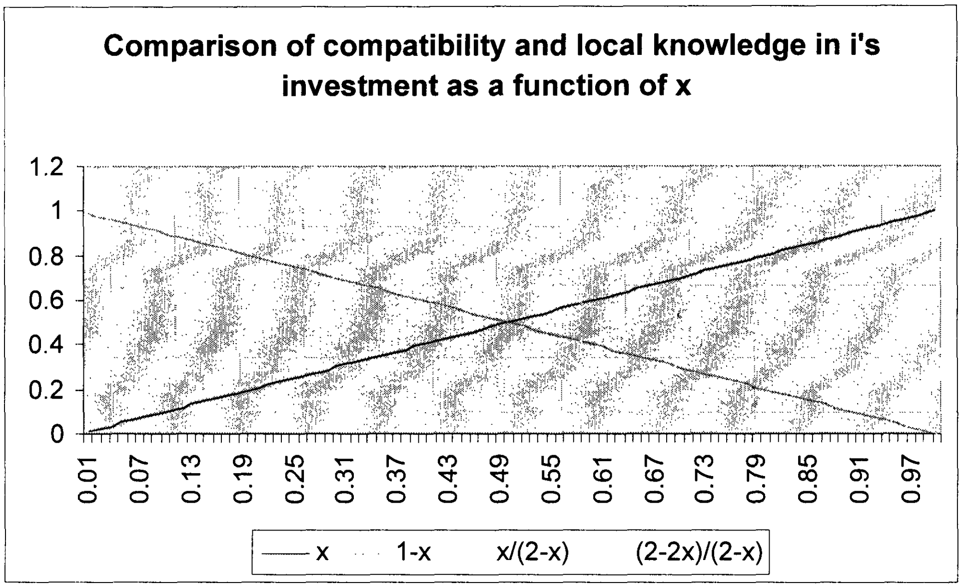

Figure 2

As can be seen on the graph, for a given value of χ, full decentralization leads to a lower weight on the compatibility component of di's action than partial decentralization. Under full decentralization, di has an incentive to underweight compatibility since the costs of incompatible technologies are shared between the two divisions. It will then overweight the investment that fits her local knowledge. Similarly, the value of $\chi$for which equal weight is assigned to both compatibility and local knowledge is lower under partial decentralization (it is equal to 1/2) than under full decentralization (2/3). As a result, a change in _ when $0 \leq \chi \leq \frac{2}{3}$ changes the relative weight between compatibility and local fit faster under partial decentralization than under full decentralization (and vice versa for $\frac{2}{3} \leq \chi \leq 1$).

The results in this section are driven by the fact that both divisions bear the cost of incompatibility when both have decision rights. If only di bears the costs of compatibility, then case 4 collapses to case 2. In this simple setting, there are therefore two main cases: whether di has decision rights or not. The case when dj **also** has decision rights influences di's actions (and payoffs) only because of the associated reward structure in which marginal costs are split between the two parties.

7.4 Optimal Choice of Decision Rights Allocation

The former analysis shows the optimal actions on the side of the two divisions under the four different regimes: full centralization, partial centralization when di gets to decide, partial decentralization when dj gets to decide, and full decentralization. Using the values of the optimal actions in equilibrium, we can determine the circumstances under which headquarters will decentralize or centralize decision rights. In order to do this, I compare the social output under the different regimes.

7.4.1 Full Centralization

Under full centralization, headquarters decide for each one of the divisions and determines the optimal action. The analysis above showed that each division will be asked to choose $ai = aj = \overline{\theta}i$. In this case, output is:

$$\begin{aligned} F_c(ai,aj,\theta i) &= E\left[\chi\left(1-(ai-aj)^2\right)+(1-\chi)\left(1-(ai-\theta i)^2\right)\right] \\ &= E\left[(1-\chi)\left(1-(\bar{\theta} i-\theta i)^2\right)\right] \\ &= (1-\chi)\left(1-\sigma^2\right) \end{aligned}$$

7.4.2 Partial Decentralization: the Case of d_j

We have seen that this case is equivalent to full centralization since each division's optimal action in equilibrium is identically equal to $\bar{\theta} i$ in this case as well. Output is then: $F_{Dj}(ai,aj,\theta i) = (1-\chi)\left(1-\sigma^2\right)$ as well.

7.4.3 Partial Decentralization: the Case of d_i

Recall that in this case, $aj = \bar{\theta} i$ and $ai = \chi\bar{\theta} i + (1-\chi)\theta i$. Given these actions in equilibrium, output is given by:

$$\begin{aligned} F_{Di}(ai,aj,\theta i) &= E\left[\chi\left(1-\left(\chi\bar{\theta} i+(1-\chi)\theta i-\bar{\theta} i\right)^2\right)+(1-\chi)\left(1-\left(\chi\bar{\theta} i+(1-\chi)\theta i-\theta i\right)^2\right)\right] \\ &= \chi\left(1-(1-\chi)^2\sigma^2\right)+(1-\chi)\left(1-\chi^2\sigma^2\right) \\ &= 1-\chi(1-\chi)^2\sigma^2+1-\chi-\chi^2\sigma^2+\chi^3\sigma^2 \\ &= 1-\chi(1-\chi)\sigma^2 \end{aligned}$$

7.4.4 Full Decentralization

The equilibrium in full decentralization was shown above to involve actions $aj = \bar{\theta} i$ and $ai = \dfrac{\chi\bar{\theta} i + 2\theta i(1-\chi)}{2-\chi}$. The output in this case is:

$$
\begin{aligned}
F_D &= \chi\left(1-\left(\frac{\chi-2+\chi}{2-\chi}\bar{\theta}i-\frac{2\chi-2}{2-\chi}\theta_i\right)^2\right)+(1-\chi)\left(1-\left(\frac{\chi}{2-\chi}\bar{\theta}_i+\frac{2(1-\chi)}{2-\chi}\theta_i-\theta_i\right)^2\right)\\
&= \chi\left(1-\left(\frac{2(\chi-1)}{2-\chi}\right)^2\sigma^2\right)+(1-\chi)\left(1-\left(\frac{\chi}{2-\chi}\right)^2\sigma^2\right)\\
&= 1-\frac{\chi(1-\chi)\sigma^2}{(2-\chi)^2}\left(-2(\chi-1)+\chi\right)\\
&= 1-\frac{\chi(1-\chi)(4-3\chi)}{(2-\chi)^2}\sigma^2
\end{aligned}
$$

The following table summarizes the optimal actions for each division in equilibrium under each regime, and the resulting output.

	ai	aj	$F_r(ai,aj,\theta i)$
Centralization	$\bar{\theta}i$	$\bar{\theta}i$	$(1-\chi)(1-\sigma^2)$
Partial Decentralization (j)	$\bar{\theta}i$	$\bar{\theta}i$	$(1-\chi)(1-\sigma^2)$
Partial Decentralization (i)	$\chi\bar{\theta}i+(1-\chi)\theta i$	$\bar{\theta}i$	$1-\chi(1-\chi)\sigma^2$
Decentralization	$\frac{\chi\bar{\theta}i+2\theta i(1-\chi)}{2-\chi}$	$\bar{\theta}i$	$1-\frac{\chi(1-\chi)(4-3\chi)}{(2-\chi)^2}\sigma^2$

Table 9

7.5 Propositions

We can now state a number of propositions that derive from the results shown above.

Proposition 1: Delegating decision rights to a division that is only partially dependent on another division leads to more diverse technological investments at the division than when decision rights are centralized

Proof: follows by inspection of ai above

Proposition 2: The effect in proposition (1) is larger if both divisions were given decision rights than if the partially-dependent division was the only division to which decision rights were delegated

Proof: follows by inspection of ai above

Proposition 3: For a given level of uncertainty in the local environment, there exists a unique degree of dependence between the divisions above which centralization is optimal and under which partial decentralization (where rights are assigned to i) is optimal. Furthermore, there is a non-zero interval for the dependence measure χ such that if χ belongs to this interval, centralization is always better, for *any* level of uncertainty in the local environment.

Proof: the cutoff value for χ is determined by $(1-\chi)(1-\sigma^2) = 1-\chi(1-\chi)\sigma^2$ which leads to the condition that $\sigma^2 = \frac{\chi}{(1-\chi)^2}$. This function is strictly increasing in χ which proves part 1 of the proposition. The second part is proved by showing that

$$\frac{\chi}{(1-\chi)^2} = 1 \Rightarrow \chi = \frac{1}{2}\left(3-\sqrt{5}\right) < 1$$

In the next section I describe a dataset that I used in order to conduct simple empirical tests of the first proposition. The empirical findings confirm the result that decentralization leads to more diverse technological investments.

7.6 Empirical Test

In order to model the choices of computer investments as a function of decision rights, I assembled micro data on establishments of a large subset of Fortune 1000 companies between the years 1995 (and a few years earlier for some sites) and 2001. Here I briefly describe the behavior found in these establishments.

The sample consists of data on personal computer investments at sites of Fortune 1000 companies and the location of the purchasing decision (parent or local). To be in the dataset, a site had to meet a number of requirements: first it had to report whether purchasing decisions were centralized (parent) or decentralized. Second, it had to be using at least one personal computer. The total number of sites meeting these conditions over the years 1995 to 2001 is 145,540. The resulting sample is therefore very large. About 59% of the sites reported that purchasing decision rights were centralized (parent), the rest of the sites being local.

Table 10 compares the locus of decision making over time. The results point to a trend towards centralization.

Year	***Frequency of sites reporting local PC purchasing decision rights***
1996	57 %
1997	51
1998	48
1999	45
2000	43
2001	40

Table 10: PC purchasing rights from 1996 to 2001

The table shows that between 1996 and 2001 there has been a 30% increase in the centralization of PC purchasing decision rights. In the framework above, this could be because firms have become more integrated, or because division dj's knowledge of division di's local conditions has become more uncertain.

In order to test the first hypothesis above, I calculated three measures of standardization: the first metric is simply the total number of different PC types at the site, tottype. A high tottype indicates that the establishment is using a lot of different PC types. The second metric, called cratio1, is a concentration ratio of the largest PC type at the site. In other words, if type A is the PC type most used at the site, cratio1 represents the share of PCs of type A among all PCs at the site. The third metric, herf, is a Herfindahl-Hirschman Index that uses the square of the shares of the different PC types at the site. A high herf index indicates that PC purchases at the site are concentrated in a few brands.

Table 11 presents statistics for these three metrics both for sites to which PC purchasing decision rights have been delegated and sites for which decision rights remain at the parent level. The table shows clearly, across all three metrics, that delegating decision rights is associated with more diversity in computer purchases. The mean number of PC types is 3.2 for "decentralized" sites and 2.2 for "centralized" sites. The Herfindahl-Hirschman Index is almost 50% higher at "centralized" sites than at "decentralized" sites.

Decision	Variable	N	Mean	StdDev	Min	Max
D	Tottype	53203	3.208	1.9	1	22
C	Tottype	54611	2.205	1.38	1	17
D	Cratio1	53189	0.41	0.25	0.03	1
C	Cratio1	54588	0.56	0.29	0.04	1
D	Herf	53189	0.37	0.24	0.03	1
C	Herf	54588	0.53	0.3	0.03	1

Table 11: Statistics for Standardization Metrics. D: Decentralized, C: Centralized

In order to control for PC usage at the site (sites with many PCs may exhibit higher values for tottype and large sites may also be delegated decision rights more often), I regressed the log of tottype on the decision rights dummy (local or parent) and the log of the number of PCs at the site as well as the log of PC per employee at the site. The results of this regression appear in Table 12. They show that controlling for the number of PCs at the site and the number of PCs per employee at the site, delegating decision rights is associated with a 30% increase in the total number of PC types used at the site.

Variable	Estimate	Standard Error	t Value	Pr > |t|
Intercept	2.186	0.00735	297.54	<.0001
Decision_right	0.29	0.01006	97.33	<.0001
Log(PC)	0.045	0.00412	152.23	<.0001
Log(PC_pemp)	0.01494	0.00388	3.85	0.001

Table 12: Regression of Log(tottype) on different variables

The results so far confirmed the hypothesis (1) that computer investments are sensitive to the location of purchasing decision rights at the firm. Consistent with the model developed in the previous section, managers responsible for technology purchasing decisions appear to diversify their IT investments.

7.7 Discussion

The empirical analysis above suggests that delegating decision rights to branch managers is associated with more diversity in IT investments at the site. A priori, this finding is not surprising: if managers are given purchasing decision rights, one could expect that they would purchase more diverse computer systems. Although the intuition is borne out in the data, delegating decision rights could theoretically lead to the opposite behavior: depending on the reward structure, if delegating decision rights is accompanied with more accountability (one of the features of the model above, in which the division that has the rights also bears some of the costs of incompatibility) then managers that are risk-averse may be more conservative in their investments than what a centralized authority would have judged optimal. This is similar to models of herd behavior in finance where fund managers were found to be less likely to take risks when their performance was evaluated relative to their peers (see Ellison et al., 2001).

In addition, if headquarters expect that branch managers to which decision rights have been delegated are more likely to invest in less-standardized IT investments, and that this behavior hurts the firm then they should not delegate decision rights. The fact that despite this behavioral pattern delegation still takes place shows that a more complicated explanation is needed . The model above presents a potential avenue to explain this behavior.

There are a number of possible extensions, including a more detailed analysis of the empirical dataset and a formal testing of the hypotheses derived from the model developed above. Future work will consider testing the two other propositions empirically and deriving additional insights from the theoretical model presented above.

7.8 Summary

The main purpose of this chapter was to develop a theoretical model of the tradeoff that firms face in deciding whether to delegate decision rights to the division managers or whether to keep them centralized. The model showed how the optimal allocation of decision rights at the firm depends both on the degree of interaction between units and the uncertainty in the local environment of the divisions. This gave rise to predictions about when different allocation regimes will arise. Preliminary testing of the model was also presented.

8 Conclusion

This thesis has examined the business transformations that accompany IT investments with a particular emphasis on the regional allocation of labor resources and the distribution of decision rights across geographically-distant business units. This research has provided important insights into two critical and interrelated management issues of information technology: the first is the importance of location and the potential for IT to substitute for location-based benefits and the second the allocation of decision rights across geographically-distant business units. Specifically I found that:

1. Lower-cost locations are more attractive to IT-intensive firms leading to cost savings of about 1% of total unit costs for every 10% increase in IT.

2. CSR employment is sensitive to the use of IT. An increase of 10% in IT usage reduces employment by 1.3% on average.

3. Idiosyncratic factors that enter firms' location decisions are non-negligible. Still regional characteristics help explain some of these preferences: location externalities (the benefits of proximity to customers, other firms or other activities at the same firm) explain part of the regional preferences. This provides support to agglomeration models in economic theory.

4. I also found that sensitivity to location characteristics is lower the more decentralized the firm is. Presumably, firms whose decision loci are decentralized may be able to take advantage of regional cost differentials by delegating authority to the division

managers. This led me to consider the reasons why managers may decide to delegate decision rights to some divisions and not to others.

5. I set up a model that describes the tradeoff that managers face when investing in information technologies: centralize decision making and achieve full compatibility or decentralize decision rights so that technology can be adapted to the local preferences and circumstances at the division level, sometimes at the expense of compatibility.

6. I derived some hypotheses from the model and showed some empirical support for these hypotheses.

The research findings in this thesis provide a useful avenue for understanding the reasons for success or failure of location policies by urging firms to recognize and account for the importance of location benefits when structuring their activities worldwide. The second is the tradeoff that firms face between achieving compatible information systems across the enterprise and still being able to access and tap local expertise. I described a model with clear implications about when and why managers should decentralize purchasing decision rights to the local divisions and when they should keep them centralized at the headquarters. The importance of these two related questions will only grow as more firms decentralize activities geographically in the "global" economy.

Appendix A

Companies in the Sample and Their Standard Industry Classification

CSICKEY	CCOMPANY
20	Coca Cola Company
20	PepsiCo Inc
20	Sara Lee Corporation
20	Anheuser Busch Companies Inc
20	Campbell Soup Company
20	Archer Daniels Midland Company
20	W M Wrigley Jr Company
20	Tyson Foods Inc
20	Coca Cola Enterprises Inc
20	Suiza Foods Corporation
28	E I du Pont de Nemours & Company
28	Procter & Gamble Company
28	Dow Chemical Company
28	Valspar Corporation
28	Colgate Palmolive Company
28	Johnson & Johnson
28	American Home Products Corporation
28	P P G Industries Inc
28	Bristol Myers Squibb Company
28	Pfizer Inc
28	Avon Products Inc
28	Merck & Company Inc
28	Abbott Laboratories
28	Pharmacia Corporation
28	Schering Plough Corporation
28	Ecolab Inc
28	Intrntl Flavors & Fragrances Inc
28	PolyOne Corporation
28	H B Fuller Company
28	Great Lakes Chemical Corporation
28	Revlon Inc
28	Praxair Inc

CSICKEY	CCOMPANY
28	R P M Inc
28	Estee Lauder Companies Inc
28	Eastman Chemical Company
35	International Business Machines
35	Caterpillar Inc
35	Deere & Company
35	N C R Corporation
35	Ingersoll Rand Company
35	Hewlett Packard Company
35	Cummins Engine Company Inc
35	Timken Company
35	Black & Decker Corporation
35	Tecumseh Products Company
35	Pitney Bowes Inc
35	Parker Hannifin Corporation
35	Milacron Inc
35	Dover Corporation
35	Silicon Graphics Inc
35	Intel Corporation
35	Storage Technology Corporation
35	S P X Corporation
35	The Toro Company
35	Kennametal Inc
35	Pentair Inc
35	Pall Corporation
35	Sun Microsystems Inc
35	Compaq Computer Corporation
35	Seagate Technology Inc
35	Baker Hughes Inc
35	Terex Corporation
35	Maxtor Corporation
35	A G C O Corporation
35	E M C Corporation
35	3 Com Corporation
35	Cabletron Systems Inc
35	Cooper Cameron Corporation
35	Symbol Technologies Inc
35	American Power Conversion Corp
36	Rockwell Automation
36	Raytheon Company
36	Eaton Corporation
36	Texas Instruments Inc
36	Vishay Intertechnology Inc

CSICKEY	CCOMPANY
36	Motorola Inc
36	Emerson Electric Company
36	Harris Corporation
36	A O Smith Corporation
36	Cooper Industries Inc
36	National Service Industries Inc
36	National Semiconductor Corporation
36	Maytag Corporation
36	Thomas & Betts Corporation
36	Amphenol Corporation
36	Molex Inc
36	Micron Technology Inc
36	Exide Corporation
36	Tellabs Inc
36	Lucent Technologies Inc
36	Fairchild Semiconductor Intrntl
36	Altera Corporation
38	Eastman Kodak Company
38	Xerox Corporation
38	Beckman Coulter Inc
38	Baxter International Inc
38	Becton Dickinson & Company
38	Medtronic Inc
38	Thermo Electron Corporation
38	Teleflex Inc
38	Boston Scientific Corporation
38	Guidant Corporation
38	Stryker Corporation
38	K L A Tencor Corporation
38	Dade Behring Inc

Appendix B

Glossary

Variable	*Associated Parameters (if any)*	*Reference*
λ	-	Arrival Rate
S_f	-	Sales (billions)
D_f	-	Characteristics of the Firm(all variables that are firm-specific)
Rf	-	Revenue from Customer Service
Pi	-	Unit Costs of CSR in Region i
X_i^f	-	Number of CSRs hired by Firm f in Region i
α	-	Order of the Polynomial that Approximates Compounded Service Time
W	-	Time-average Waiting Time
Z	-	Service Time
V_i	-	Regional Characteristics (all variables that are region-specific)
μ_{if}	-	Marginal Value of CSR in Region i to Firm f
$m(D_f)$	-	Vertical Differentiation Coefficient (a Polynomial)
IT	f_1, m_1	IT Variable
G	f_3, m_3	Number of Industry Segments
D	m_2	Decentralization Variable
UC	-	Unit Costs (P in the model)
TI	β_2	Telecom Infrastructure
LS	β_3	Proximity Variable

LF	β_1	Availability of the Labor Pool in the Region
S_j	γ	State Dummy Variable
$\overline{CSR}$	f_2	Average Number of CSRs in the Industry
ND	f_4	Dummy Variable for Non-Durable Industries

Table 5 Glossary of the variables in the model. For the variables that enter the econometric specification, the associated parameters are included as well.

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