THE EFFECT OF INFORMATION TECHNOLOGY
ON PRODUCTIVITY IN THE
RETAIL SECTOR

DISSERTATION

Presented to the Graduate Council of the
University of North Texas in Partial
Fulfillment of the Requirements

For the Degree of

DOCTOR OF PHILOSOPHY

By

James F. Reardon, B.S., M.B.A.

Denton, Texas

August, 1995
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Comparative levels of productivity affect not only individual firms, but also affect the aggregate performance of economies. As the service sectors of industrialized economies continue to expand relative to other sectors, pressures for productivity growth will increase. Retailing is responding to this pressure by adopting a number of strategies, including the implementation of information technology. It is uncertain, however, to what degree information has improved productivity in the retail sector.

Three major research questions were addressed in this study. First, does information technology contribute to the productivity of retail institutions? Second, to what degree can information technology be substituted for labor and capital in retailing? Finally, is the market efficient in allocating information technology? These questions were chosen after a careful review of the literature revealed gaps in these areas.

A non-probability sample of 871 stores was surveyed from within the Dallas-Fort Worth CMSA. Of these, 521 surveys (59.8 percent) included enough information to compute the output measure. The output measure, value added, was calculated from sales in conjunction with either gross margin percentage or cost of goods sold.
Cobb-Douglas and transcendental logarithmic (translog) production functions; were estimated for each type of independent variable: physical; monetary; and weighted. Two major analytic methods were used to manipulate the data: Ordinary Least Squares (OLS) regression for the aggregate sample and Two-Stage Least Squares (2SLS) regression for the analysis by SIC categories.

The findings indicate that information technology is a productive factor in retailing. Indeed, the results that suggest information technology contributes as much on the margin as spending on additional selling space. The results of the study also suggest retailers may be under-utilizing information technology, thus incurring an opportunity cost.
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CHAPTER I

INTRODUCTION

Productivity is a central theme in the current business environment. Comparative levels of productivity affect not only individual firms, but also affect the aggregate performance of economies. As the service sectors of industrialized economies continue to expand, pressures for productivity growth in all industries will increase. Retailing, as a major force in the service sector, is responding to this pressure by adopting a number of strategies, including the implementation of information technology to improve performance. It is uncertain, however, to what degree the implementation of information technology increases retail productivity. This dissertation will endeavor to address this issue.

In the following section, the purpose and scope of the research is discussed. This is followed by a discussion of the importance of conducting research in this particular area. The main body of the chapter includes a brief discussion of issues relating to the research. Among these are societal and firm level issues focusing on productivity in the service sector, and a discussion specifically related to the productivity of information technology at the retail level. The specific research questions addressed in this investigation, followed by a listing of the hypotheses are
also included. The chapter concludes with a summary and an overview of the remaining chapters of the dissertation.

**Purpose and Scope of Research**

The purpose of this study is to explore the contribution of information technology to the productivity of retail institutions. No widely accepted definition of information technology currently exists. For the purposes of this study it is defined as advancements in knowledge which are applied to gain access to more and/or better information.

Retailing, by definition, consists of the exchange of goods and services with the final consumer. The scope of retailing is far too broad for a single study. It is therefore necessary to limit the scope of this study to product-based retailing, as identified by their Standardized Industry Classifications (SIC) codes. The eight areas are: 1) building materials and garden supplies stores (5200-5299); 2) general merchandise (5300-5399); 3) food stores (5400-5499); 4) automotive stores (5500-5599); 5) apparel and accessory stores (5600-5699); 6) furniture and home furnishings (5700-5799); 7) eating and drinking places (5800-5899); and 8) miscellaneous retail stores (5900-5999). These areas allow for study of a diverse group of retailers and yet maintain some level of homogeneity within the groups. Also, a pilot survey showed these industries to be diverse in their level of utilization of information technology. This variation encourages greater precision and internal validity of the research results.
Justification of Research

The justification for this research stems from the importance of productivity gains to the economy, firms, and consumers. As discussed in the following section, productivity has a direct effect on both the standard of living in an economy and a firm's competitive position (Ingene 1982). As labor becomes relatively more expensive (Bucklin 1978; McCready 1991), firms will attempt to substitute other factors of production, such as information technology, for labor. However, it is unknown if, and to what extent, information technology can be efficiently substituted for either labor or capital in the retail industry.

Gains in productivity due to the adoption of information technology by firms tend to be elusive. While some are found in specific firms or industries, findings of overall gains remain limited. Such documentation of gains, or lack thereof, tends to be based on anecdotal evidence or specific case studies. The lack of correlation between spending on information and gains in productivity in the service sector during the eighties is often cited as evidence that there are no productivity gains from the implementation of information technology (Levy 1993; Labbe 1993; Krohe 1993; Davis 1991; Diebold 1990; Keyes 1990). However, this may also be attributed to other factors, such as an economic recession. A thorough cross-sectional study of retail institutions in a single geographic area allows economic and other exogenous variables to be held constant. This provides more compelling evidence for the contribution, or lack of contribution, of information technology to productivity. It also
provides an empirical measure of the effects of information technology on the productivity of retail firms.

Over $800 billion dollars has been spent on information technology in the service sector (Meltzer 1993). However, the effect of this expenditure is not yet understood. Several researchers refer to the lack of correlation between spending on information technology and expected gains in productivity as the "productivity paradox." Brynjolfsson (1993) states that:

The relationship between information technology (IT) and productivity is widely discussed, but little understood. The increased interest in the productivity paradox, as it has become widely known, has engendered a significant amount of research, but thus far, has only deepened the mystery.

Furthermore, he indicates that:

After reviewing and assessing the research to date, it appears that the shortfall of IT productivity is as much due to deficiencies in the measurement and methodological tool kit as to mismanagement by developers and users of IT.

While he suggests that comprehensive studies using advanced methodological analysis be undertaken, no one has yet conducted such research.

The first major justification of this research is that retailers need to know, not only if, but also how much, productivity can be improved through the implementation
of information technology. Second, retailers need to identify if, and to what extent, information technology can be substituted for more expensive factors of production.

The last, and perhaps most important justification for this research, is the contribution that it will make to knowledge in marketing. This research will extend the Theory of the Firm to the retail sector. While this has been done by authors in the past, this is the first attempt to incorporate differing levels of information technology into the production function and test the efficiencies of the market for information technology in the retail sector.

This research will expand current theory by addressing the following theoretical areas: 1) the measurement of information technology as a factor of production; 2) the substitutability of information technology for labor or capital; and 3) the efficiency of the market mechanisms in allocating information technology.

Productivity Defined

In order to meaningfully discuss the issue of productivity, it first must be defined. Productivity is the output that can be gained from a single unit of factor input (Henderson and Quandt 1986). The most common measure of productivity in marketing, specifically retailing, is labor productivity (Kelly, Donnelly and Skinner 1990), defined as the amount of output for each unit of labor. However, both in marketing and economics, several other aspects of productivity have been measured and studied. Among the more prominent of these is capital productivity. Productivity,
both labor and capital based, has received a great deal of attention in the literature for
good reason (Ingene 1982, 1984a, 1984b, 1985; Takeuchi and Bucklin 1977). As
discussed in the next section, the concept of productivity is central to both the standard
of living in an economy (Berry 1990) and the well-being of individual firms (Ingene
1984).

**Productivity at the Societal Level**

Productivity is a major determinant of a country's relative standard of living
both across time and between countries. Bauer (1992) attributes the slow improvement
in the U.S. standard of living to two decades of slowing growth in productivity. In
order to significantly increase the standard of living over time, a country must increase
the productivity of its resource base from year to year. Likewise, to become relatively
more competitive in a global economy, a country must, among other things, increase
its factor productivity at a faster rate than other countries (English and Marchione
1983). Kronemer (1993) indicates that productivity is the primary means of increasing
income levels and is an important determinant of the ability to compete worldwide.
Increases in productivity result in lower aggregate prices and higher national incomes
while declines have opposite effects (Kronemer 1993).

As the United States becomes more service oriented, the productivity of service
firms will have a greater effect on the relative standard of living (Bucklin 1978; Ingene
1984; Bauer 1992). Cantwell (1991) argues that the United States can not maintain its
current standard of living if it primarily becomes a provider of services. Furthermore, Shea (1992) suggests that retailers must be proactive in addressing several fundamental issues, including embracing information technology, or it will become a drag on the economy, damage consumer confidence, and be perceived as a prime cause of the recession.

In 1993, over 70 percent of the U.S. Gross National Product (GNP) was derived from services. A large portion of this was accounted for in the retail sector, yet the service sector, retailing in particular, has experienced relatively slow productivity growth (Achabal and McIntyre 1987). In the postwar period the growth rate of labor productivity in retailing has been lower than that in other major sectors of the economy (Ingene 1982; Herman 1990).

While productivity in retailing has shown growth in the last few years, 2.4 percent in 1992, this growth is well below that of other sectors of the economy (e.g. steel, 10.5; metal forming machine tools, 20.3; coal mining, 10.7; copper mining, 14.3; railroads, 9.7; telecommunications, 6.5; and electric utilities, 4.9) during the same time period (Herman 1990). Productivity growth in the U.S. service sector is also below that of other economies (English and Marchione 1983; Evans 1992). Thus the study of productivity is of fundamental importance, especially with regard to the below average growth rate found in the retail sector.

The low rate of productivity growth in U.S. retailing has been a major social concern (Takeuchi and Bucklin 1977). During the eighties, productivity in the service sector grew at an annual rate of 1.9 percent. During the same time period productivity
grew at a rate of 44 percent in the manufacturing sector (Schnitt 1993). Thus, productivity growth in the service sector is growing at a slower rate than the manufacturing and agriculture sectors, while at the same time expanding output 12.47 and 36.03 percent faster than the manufacturing and agriculture sectors, respectively, since 1970.

The displacement of high productivity manufacturing with the relatively lower productivity service sector raises a great deal of concern for the future economic welfare of the United States. Ingene (1982) goes as far as to suggest that, because of the economic shift to the relatively less productive service sector, the United States can expect a decline in its standard of living. More recently, Shea (1992) and Cantwell (1991) have adopted similar positions. Also, Bernstein (1991) has indicated that the current generation may be the first in American history to be less well off than the previous generation.

Because of productivity's strong influence on the economy, concern about productivity growth has received wide attention from world governments and has been the focus of several governmental committees. In 1970, the Commission on Productivity was established by President Nixon in response to competitive pressures from overseas. Funding for the Commission was cut off in 1974 by Congress, but was soon reestablished as the National Commission on Productivity and Work Quality. While this committee has been reorganized and renamed several times, productivity issues continue to receive governmental attention at the national level of government. In its current form, The Council on National Competitiveness, it has been responsible
for a significant amount of research. It periodically publishes an index which compares U.S. productivity and standard of living with those of other countries (Harrison 1992). Interestingly, other countries established their own centers for productivity earlier than the United States, often with U.S. assistance. The European Productivity Agency was established in 1953 with a grant from the United States and Japan established the Japanese Productivity Center in 1955. These efforts at increasing national productivity are indications of its importance to countries' economies (Weber 1990).

Productivity at the Firm Level

Productivity of individual firms affects their competitive position and their overall profitability (Ingene 1984). Firms that fail to keep pace with their industry often experience financial problems. A National Retail Merchants Association publication (1982) was entitled *Productivity: The Key to Survival in General Merchandise Retailing*. This exemplifies past concerns in the retail industry regarding productivity improvements. These concerns continue to plague the retail industry (Loeb 1990).

Retailing is subject to fierce competitive pressures due to relatively low entry barriers. In such an environment, a retailer must achieve high productivity in order to stay competitive. Retailers are constantly trying to improve productivity by increasing the efficiency and effectiveness of their operations. In the search for greater productivity, retailers have invested billions of dollars in information technology. K-
Mart, for example, has invested over $1 billion in information technology (Mandell 1991).

Several authors have suggested that competitive advantage can be gained through the use of information technology. Harrison (1991) indicates that things such as improved in-store systems can boost both labor and space productivity and thereby create a competitive advantage. Porter and Millar (1985, p.149) also suggest that information technology can be used to create a competitive advantage by supporting cost and differentiation strategies.

As indicated by Bucklin (1978), productivity measures have the potential to be used by retail firms for five functions. He categorizes these as: 1) evaluation of the competitive position of a firm; 2) judging improvements derived from changes in technology; 3) providing standards for motivating and rewarding personnel based on performance; 4) forecasting factor needs (labor and capital) of the firm; and 5) assisting in making marketing and distribution decisions. Ingene (1984), among others, also indicates that retail productivity studies have the potential to serve a variety of managerial and societal concerns. This research is limited to the second of Bucklin’s purposes: the examination of technology improvements across firms.

**Importance of Retail Productivity Issues**

Studies in the academic literature have concentrated on both labor and capital productivity in retailing. Cox first discussed the measurement and meaning of
productivity in distribution as early as 1948. In the late seventies and throughout the
eighties, the majority of research on retail productivity was conducted and published.
While there remains need for research in retail productivity, there has been little done
in the last decade. Among the more preeminent researchers in this area are Bucklin
1985), who have focused a great deal of attention on and contributed to the
understanding of retail productivity. The knowledge that these and other authors have
contributed supports several broad areas of research regarding productivity.

The first area regards the scope of production in retailing, first examined by
Hollander (1961). He suggested that a retailer could either produce utility or shift the
production to the customer, wholesaler, or to a contractor. In another area, Ingene
(1982) has been instrumental in examining the relationship between productivity and
the structure of retailing. Finally, several other authors have contributed to the
knowledge of productivity of capital and labor at the store level (Thurik and Van Der
Wijst 1984; Good 1984; Doutt 1984; Arndt and Olsen 1975). These and other studies
are reviewed in more detail in Chapter II (Review of Literature).

Companies have devoted a great deal of resources to productivity issues. In a
recent study, McKinsey and Co. indicated that while productivity in the United States
is still above that of its major competitors, this margin is quickly shrinking (Bernstein
1992). One possible explanation for this is that labor costs are increasing faster than
inflation, profitability, or sales (McCready 1991). This has encouraged companies to
either increase the productivity of labor or substitute other factors of production for
labor (Bucklin 1978; Ingene 1984b; McCready 1991). Most studies have shown a disproportionate contribution of labor to retailing output (Ingene 1984b), giving companies high incentives to reduce labor cost per unit of output. Many retailers have attempted to accomplish this through the implementation of information technology.

**Retail Productivity and Information Technology**

Several authors directly attribute the productivity growth in retailing to advances in technology (e.g. McCready 1991; Friedman 1988). However, empirical evidence that this is the case remains limited. The growth may also be attributed to other factors, such as increased demand or overall economic expansion (Davis 1991). Therefore, it is important to determine if information technology contributes to productivity in retailing and, if so, to what extent.

Labor and capital have received wide attention with regard to productivity in retailing. However, other areas such as technology have not. Yet authors such as Ferrero (1991) indicate that:

Managers throughout the world understand that information technology has become a factor of productivity on par with labor, land materials, and equipment.

The lack of attention in this area can be partly attributed to the fact that the roots of this stream of research are in economics, where technology is often assumed to be constant across firms (Henderson and Quandt 1986, p 66). The economics literature defines
technology as "all the information about the combination of inputs necessary for the production of output" (Henderson and Quandt 1986, p 66). This information is assumed to be free and equal to each firm. In other words, economists often assume free and perfect information. Other problems, such as difficulties in measurement (Achabal, Heineke, and McIntyre 1984 1985; Goodman 1985), also may contribute to the lack of research with regard to technology.

Most research on the productivity of information technology has either been anecdotal in nature or refers to manufacturing firms. There have been serious questions as to the contribution of information technology to productivity in general and to retail productivity in particular. Information technology accounted for 42 percent of all business equipment expenditures in 1988 (Kominski 1991). However, evidence indicates that this investment has not been productive (Betts 1994; Meltzer 1994; Rudd 1993; Levy 1993). Ray (1994) indicates that information technology may actually limit productivity gains instead of increasing them. Thachenkary (1993) indicates that during periods of high spending on information technology, capital productivity actually decreased. Meltzer (1993) suggests that while business expenditures in information technology grew to nearly $1 trillion, this failed to translate into measurable gains in productivity. This is especially true for the service sector, which accounted for as much as 80 percent of these expenditures (Meltzer 1993). The business press has coined terms such as "productivity pit" (Krohe 1993) to describe the relationship between information technology and the current state of productivity in the U.S. service sector.
Evidence indicates that the lack of correlation between productivity gains and spending on information technology is not unique to the United States. Canadian firms have invested over $15.5 billion in information technology and have yet to experience improvements in white-collar productivity (Marsden 1992; Whaley 1992). It should be noted that most of this evidence is anecdotal in nature and therefore should be treated with a degree of skepticism.

Several possible explanations have been provided for the lack of productivity gains associated with increases in information technology spending. Among these are failure of measurement instruments (Metcalf 1992); inability to account for gains in quality of services (Rudd 1993); misuse of technology (Manzi 1992); failure to provide structures and processes that facilitate the use of information technology (Loveman 1991); failure to completely integrate the technology and the firm (Schnitt 1993); lack of management involvement (Davis 1991); and the selective ability of computers to encourage one to do essentially useless work (Levy 1993).

Senior executives have also started to question the value and cost of adding more and more information technology. There are indications that information technology costs may be out of control in the private sector of the economy (Keen 1991).

Other studies have shown gains in productivity from investments in information technologies. Berry (1990, p. 6) states that "the most significant key to productivity may be technological progress." There are many in the academic press, the popular press, and management that tend to agree. Evidence is inconclusive as to whether
productivity gains in retailing are consistent with high spending on information technology. However, there are several case studies and much anecdotal evidence that support firm or industry specific gains in productivity. The question remains as to the size and significance of productivity gains from information technology in the retail sector.

**Statement of Research Questions**

Three major research questions are addressed in this study. First, does information technology contribute to the productivity of retail institutions? Second, is the market efficient in allocating information technology? Finally, to what degree can information technology be substituted for labor and capital in retailing? These questions were chosen after a careful review of the literature exhibited gaps of knowledge in these areas, as discussed in Chapter II. In addition, these questions are often raised by retailers.

**Statement of Hypotheses**

Each of the hypotheses is developed and discussed in detail in Chapter III. A brief overview is presented here as a convenience to the reader. The first hypothesis concerns the overall productivity of information technology in retailing (see research question one).
H1: Information technology has a statistically significant positive effect on the output of retail institutions.

The second and third hypotheses constitute an attempt to study the efficiency with which the market allocates and distributes information technology (see research question three). According to economic theory, in the absence of market imperfections, the distribution of input factors should be such that the overall welfare of the system is maximized by the efficient allocation of resources between firms. This concept needs to be tested in a retail setting.

H2: The economies of scale in retailing are equal to one (i.e. Retailers have a production function that is homogeneous to degree one).

H3: Information technology is paid the value of its marginal product.

The last set of hypotheses pertains to the ability of retailers to substitute one production factor for another (see research question two). While this type of analysis is common in economic studies of industrial firms, it has not yet been examined in the retail context.

H4a: The Rate of Technical Substitution (RTS) between information technology and capital, as measured in dollars, is equal to one.

H4b: The Rate of Technical Substitution (RTS) between information technology and labor, as measured in dollars, is equal to one.
Chapter Summary

This chapter examines the reason for and the value of studying the potential contribution of information technology to productivity in the retail sector. There exists a great deal of discussion in the business press about the productivity of information technology. While few argue this form of technology is injurious to a retail firm, there has been little formal research to suggest that it is being utilized effectively. This study endeavors to increase the knowledge in this area by providing a rigorous empirical test of the issues at hand.

The dissertation consists of five chapters. Chapter II will present a review of the literature, specifically focusing on the history of research relating to retail productivity. Chapter III outlines the methodology for the study. Specifically, the sample, research design, and measures are described. In Chapter IV the results of the research effort are presented. Chapter V concludes the dissertation with a discussion of the findings and the implications for retail theory and the potential effect on retail firms.
CHAPTER II

REVIEW OF LITERATURE

This chapter will concentrate on reviewing the culmination of knowledge in the area of retail productivity. It begins with a brief history of research relating to productivity issues in retailing, including a discussion on past definitions of the term productivity. A major segment of this chapter discusses previous studies in retail productivity and their findings. This leads into a discussion of information technology as a productive factor and specific types of information technologies defined in the literature.

History of Productivity in Retailing

Historically, a disproportionate share of productivity growth has occurred in the manufacturing sector (Bucklin 1978). Additionally, in the postwar period, the growth rate of labor productivity in the retailing sector has been lower than in other major sectors of the economy (Kendrick 1973; Kendrick and Gossman 1980; Ingene 1982). This, coupled with the fact that the U.S. economy is becoming more service oriented, has led authors such as Ingene (1982) to suggest that the manufacturing sector alone cannot continue to assume the majority of the burden of continued productivity growth.
in the economy. He further suggests that "if productivity in marketing does not increase, marketers would receive much of the blame for higher prices" (Ingene 1982 p.75). Concern over relatively lower productivity growth in the retail sector has also been expressed by several other authors (Takeuchi and Bucklin 1977; Archabal and McIntyre 1987; Herman 1990; Shea 1992).

The issue of productivity in marketing channels extends back to Cox (1948). However, it was not until 1961 that the first empirical study appeared regarding productivity in retailing (Hall, Knapp and Winsten 1961). Other early empirical examinations of retail productivity were completed by George (1966), Tilley and Hicks, (1970), Schartzman (1971), Arndt and Olsen (1975), Bucklin (1978), and Lusch and Ingene (1979).

This stream of research started gaining widespread attention in marketing with the publication of Ingene's (1982) influential article in the *Journal of Marketing*. His article was quickly followed by a special issue of the *Journal of Retailing*, Fall 1984, devoted exclusively to productivity issues in retailing. As stated by Doutt (1984), productivity problems in retailing had received little empirical research attention prior to 1984. Most previous work in this area was conceptual, which attempted to define productivity and show its usefulness as a concept (e.g. Cox 1948; Lockley 1951). Researchers still have problems with the definition and measurement of the term productivity when applied to the retail sector (Archabal, Heinke, and McIntyre 1984 1985; Goodman 1985).
Defining Productivity

A disagreement over the proper definition and use of the term productivity is evident in the literature. The term is interpreted in various ways depending upon the intent of the authors. Fensek (1964) discusses various interpretations by well-known scholars. He indicates that productivity has been viewed as:

1) the rate at which we convert work and raw materials into useful goods and services;
2) a measure of efficiency with which the resources at work are utilized;
3) a measure with which the resources are converted into commodities and services men want;
4) the degree to which the power to make or provide goods or services having exchange value is utilized;
5) the utilization of resources in relation to some standard;
6) a ratio between output and input associated with given productive activities;
7) any ratio of output of a worker, machine, plant, or industry to the amount of one of the factors of production used or to some weighted sum of the amounts of two or more factors;
8) the ratio between units of results obtained and units of effort or expenditure required to gain output; and/or
9) a measure of performance potential.
Interpretations of productivity tend to differ depending on the background of the researcher and the context in which productivity is discussed. Takeuchi (1977) indicates that researchers from four different disciplines tend to examine productivity in distinctive ways. Economists interpret productivity on the basis of a production function. Accountants take the view that productivity should be studied from a cost-accounting base. Engineers examine the construct through work measurement. Lastly, organizational theorists examine the area from a view of human relations and organizational design.

Differing uses of productivity are also common in management and marketing. Bucklin (1978) states that:

*Although the fundamental concept of productivity is not complex, it is frequently employed loosely or erroneously in the management literature. In particular, the terms 'productivity' and 'profitability' are often used interchangeably.*

He further suggests that productivity is a measure of work efficiency, which is measured by the ratio of physical output to the quantity of input.

Several researchers such as Achabal, Heineke, and McIntyre (1984 1985); Goodman (1985), and Ingene (1984) have devoted their efforts toward clarifying the construct of productivity. They discuss and define the differences between productivity, efficiency and effectiveness. They conclude that "these concepts, although related, are quite distinct" (Achabal, Heineke, and McIntyre 1984, p. 108). Disagreeing with the usefulness of traditional definitions of productivity, English and
Marchione (1983) suggest that while the definition of productivity as the ratio of physical inputs to physical outputs is technically correct, this definition may raise more questions than it answers. However, many researchers have continued to use both the term and concept of productivity.

The most common interpretation of the term productivity is expressed by Bucklin (1978) and later by Ingene (1982), who states that:

Total factor productivity is the ratio of all outputs to all inputs. Partial input productivity is the ratio of all outputs to a single input.

This has become the most widely used interpretation of productivity in examination of the retail sector. Nearly all studies of retail productivity, both from industry and academia, use a ratio of outputs to inputs as a measure of productivity.

Overview of Past Literature

Two major streams of research have developed in the area of retail productivity. Ratchford and Stoops (1988) indicate that "past studies of retail productivity have taken either a micro/managerial or a macro/societal perspective" (p. 242). These represent the most commonly studied areas of retail productivity.
As introduced in Chapter I, several societal implications arise from marketing productivity issues. Among these are:

1) productivity affects the standard of living in a society (Ingene 1982; Berry 1990);
2) there exists a relationship between productivity and government policies (Lundberg 1972);
3) transformation and redefinition of employment can occur because of changes in productivity between industries;
4) marketing expenses represent an inordinately high proportion of the cost of goods and services to the final consumer, and therefore affect prices that the consumer pays (Bucklin 1978);
5) productivity affects the level of real incomes (McCammon and Hammer 1974); and
6) the relative productivity of countries determines their respective ability to compete in global markets (Bauer 1992).

Ingene (1982; 1984) indicates that the shift of the U.S. economy to a less productive service sector could potentially have the effect of decreasing the standard of living. However, he also implies that this decline can be avoided if we sufficiently increase the productivity of the service sector.
Macro studies of productivity in retailing have concentrated mostly on structural issues. Selected studies in this stream are shown in Table 2.1. Most use labor productivity as the dependent variable and retail structure variables as antecedents. The purpose of these studies is to examine the correlates of labor productivity in retailing. These were among the first productivity studies in the retail area.

The studies in Table 2.1 indicate that several structural variables are correlated to retail productivity. In general, studies find income levels, store size, market growth, wage rates, use of part-time employees, mobility, and service level to be positively correlated with labor productivity. Congestion, competition, and chain membership tend to be negatively correlated with labor productivity. Unfortunately, few authors provide strong theoretical support for their findings.

The research conducted in this stream is conspicuously lacking in theory. While several authors suggest that there are correlations between labor productivity and other variables, they fail to give solid justification for their findings. One of the most studied correlates of labor productivity in retailing is a measure of capital, as shown in Table 2.1. The current research closely examines the relationship between capital, labor, and information technology using a theoretically sound concept.
### TABLE 2.1

**MACRO/SOCIETAL STUDIES**

<table>
<thead>
<tr>
<th>REFERENCE</th>
<th>MEASURE</th>
<th>INDEPENDENT VARIABLES</th>
<th>OBSERVED EFFECT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hall, Knapp, and Winsten (1961)</td>
<td>sales/employee</td>
<td>per capita income</td>
<td>positive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>growth rate</td>
<td>positive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>population density</td>
<td>negative</td>
</tr>
<tr>
<td>George (1966)</td>
<td>sales/FTE</td>
<td>per capita income</td>
<td>positive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>sales/store</td>
<td>positive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% sales in co-ops</td>
<td>positive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>labor market tightness</td>
<td>positive</td>
</tr>
<tr>
<td>Tilley and Hicks (1970)</td>
<td>sales area (square feet)</td>
<td>transaction value</td>
<td>positive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>customer density</td>
<td>negative</td>
</tr>
<tr>
<td></td>
<td></td>
<td>sales / sq ft</td>
<td>negative</td>
</tr>
<tr>
<td></td>
<td></td>
<td>profit / sq ft</td>
<td>negative</td>
</tr>
<tr>
<td></td>
<td></td>
<td>costs / sq ft</td>
<td>negative</td>
</tr>
<tr>
<td></td>
<td></td>
<td>net profit / sq ft</td>
<td>negative</td>
</tr>
<tr>
<td>Schwartzman (1971)</td>
<td>sales/employee</td>
<td>per capita income</td>
<td>negative</td>
</tr>
<tr>
<td></td>
<td></td>
<td>wage rate</td>
<td>positive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>sales/store</td>
<td>positive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>sales/household</td>
<td>negative</td>
</tr>
<tr>
<td></td>
<td></td>
<td>sales</td>
<td>negative</td>
</tr>
<tr>
<td></td>
<td></td>
<td>gas exp/household</td>
<td>positive</td>
</tr>
</tbody>
</table>
# TABLE 2.1 (continued)

## MACRO/SOCIETAL STUDIES

<table>
<thead>
<tr>
<th>REFERENCE</th>
<th>MEASURE</th>
<th>INDEPENDENT VARIABLES</th>
<th>OBSERVED EFFECT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arndt and Olsen (1975)</td>
<td>gross profits /employee</td>
<td>floor space (m²)</td>
<td>positive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>service level</td>
<td>positive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>chain membership</td>
<td>negative</td>
</tr>
<tr>
<td></td>
<td></td>
<td>multiple store</td>
<td>positive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>assortment</td>
<td>not shown</td>
</tr>
<tr>
<td></td>
<td></td>
<td>location</td>
<td>positive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ownership type</td>
<td>not shown</td>
</tr>
<tr>
<td></td>
<td></td>
<td>years of business</td>
<td>not shown</td>
</tr>
<tr>
<td>Bucklin (1978)</td>
<td>sales/FTE</td>
<td>per capita income</td>
<td>positive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>growth rate</td>
<td>insignificant</td>
</tr>
<tr>
<td></td>
<td></td>
<td>stores per capita</td>
<td>negative</td>
</tr>
<tr>
<td></td>
<td></td>
<td>pop density</td>
<td>insignificant</td>
</tr>
<tr>
<td></td>
<td></td>
<td>wage rate</td>
<td>positive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>department sales</td>
<td>negative</td>
</tr>
<tr>
<td></td>
<td></td>
<td>time variable</td>
<td>positive</td>
</tr>
<tr>
<td>Inge (1982)</td>
<td>sales /employee</td>
<td>ft² / # employees</td>
<td>positive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>floor space (ft²)</td>
<td>negative</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ft² / capita</td>
<td>negative</td>
</tr>
<tr>
<td></td>
<td></td>
<td>wage rate</td>
<td>positive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>population growth</td>
<td>insignificant</td>
</tr>
<tr>
<td></td>
<td></td>
<td>competition</td>
<td>positive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>EBI</td>
<td>positive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>autos/household</td>
<td>positive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>autos/square mile</td>
<td>negative</td>
</tr>
</tbody>
</table>

**NOTE:** Study repeated in 1985
<table>
<thead>
<tr>
<th>REFERENCE</th>
<th>MEASURE</th>
<th>INDEPENDENT VARIABLES</th>
<th>OBSERVED EFFECT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nooteboom (1983)</td>
<td>sales /employee</td>
<td>% change in wages</td>
<td>positive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% part-time labor</td>
<td>positive</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% unemployment</td>
<td>insig</td>
</tr>
<tr>
<td></td>
<td></td>
<td>% change in sales/store</td>
<td>positive</td>
</tr>
<tr>
<td>Ratchford and Brown (1985)</td>
<td>Adapted Production Function</td>
<td>% growth rates over time of productivity:</td>
<td>Descriptive percentages:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Overall</td>
<td>1.63 to 2.31</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Labor</td>
<td>-.36 to 1.81</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Capital</td>
<td>2.44 to 3.49</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Service</td>
<td>2.93 to 3.85</td>
</tr>
</tbody>
</table>
Managerial/Micro Studies

The second major research tradition consists of studies that examine the issue at the individual store level. This stream of research examines the effect of internal variables on retail output. For example, Arndt and Olsen (1975) examined the contribution of the amount of labor, as measured by the number of employees, and the amount of capital, as measured by the amount of floor space, to the contribution of producing output. Their findings indicate that the elasticity of labor ranges from 0.76 to 1.51, while the elasticity of capital ranges from negative 0.28 to positive 0.35. This indicates that not only did labor have a greater relative contribution, but also that some retailers have too much space. This and other major empirical studies of this stream are shown in Table 2.2.

In general, the results indicate that labor contributes a disproportional amount to output. With only a few exceptions, the coefficient of the labor variable tends to be larger than 0.50, sometimes ranging above 1.0. Coefficients of the capital variable tend to range near 0.3, periodically appearing negative. In general, it can be concluded that labor contributes more toward the creation of retail output than capital (Ingene 1986).

This stream of research is closely related to the current research project in that it tests the effects of specific factors, capital and labor, on retail output. The current research extends this stream to include information technology as a factor of production.
<table>
<thead>
<tr>
<th>REFERENCE</th>
<th>FUNCTIONAL FORM</th>
<th>OUTPUT MEASURE</th>
<th>INPUT MEASURES</th>
<th>ESTIMATE EFFECT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arndt and Olsen (1975)</td>
<td>Cobb-Douglas</td>
<td>Gross Profits</td>
<td># Employees</td>
<td>L = 0.76 to 1.51</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Floor Space</td>
<td>K = .28 to 0.35</td>
</tr>
<tr>
<td>Lusch and Ingene (1979)</td>
<td>Cobb-Douglas</td>
<td>Sales</td>
<td>$ Assets</td>
<td>K = .054 to .635</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gross Margin</td>
<td>(ft²)</td>
<td>K = .278 to .541</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Transactions</td>
<td>Wages</td>
<td>L = .317 to .809</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>FTE</td>
<td>L = .517 to .783</td>
</tr>
<tr>
<td>Ingene (1984)</td>
<td>Cobb-Douglas</td>
<td>Average sales/store</td>
<td>(ft )</td>
<td>K = -.04 to .493</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td># emp/store</td>
<td>L = .638 to 1.03</td>
</tr>
<tr>
<td>Thurik &amp; Van der Wijst</td>
<td>L = f(Q1,Q2,wages,</td>
<td>Sales</td>
<td>Hours of Labor</td>
<td>Part-time has positive</td>
</tr>
<tr>
<td>Lusch and Moon (1984)</td>
<td>Q = f(Labor)</td>
<td>Value Added</td>
<td>Employee</td>
<td>Positive</td>
</tr>
<tr>
<td></td>
<td>(Mktg vars))</td>
<td></td>
<td>Location</td>
<td>Sig</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Prices</td>
<td>Positive</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Inventory type</td>
<td>Insig</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Advert type</td>
<td>Negative</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Owner</td>
<td>Sig</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Wages</td>
<td>Sig</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fr²</td>
<td>Positive</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Deprec/payroll</td>
<td>Insig</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Positive</td>
</tr>
<tr>
<td>Doutt (1984)</td>
<td>Cobb-Douglas</td>
<td>Value Added</td>
<td>Hours</td>
<td>L = 0.88</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Insured value</td>
<td>K = 0.19</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Capacity</td>
<td>.05 insig</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Ownership</td>
<td>-.03 insig</td>
</tr>
<tr>
<td>REFERENCE</td>
<td>FUNCTIONAL FORM</td>
<td>OUTPUT MEASURE (Q)</td>
<td>INPUT MEASURES</td>
<td>ESTIMATE EFFECT</td>
</tr>
<tr>
<td>---------------------------</td>
<td>----------------------------------------------------------------------------------</td>
<td>--------------------</td>
<td>--------------------------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Good (1984)</td>
<td>Productivity = f{(sqft) + (ft)^2 + sales/ft^2 + technology + hrs/ft^2}</td>
<td>Labor Productivity</td>
<td>ft^2</td>
<td>K = 0.37</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(ft^2)^2</td>
<td></td>
<td>K^2 = -0.008</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Value Added /Hour</td>
<td>Sales/ft^2</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Tech deficient</td>
<td>-1.49</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hours/ft^2</td>
<td>-0.23</td>
</tr>
<tr>
<td>Thurik and Kooiman (1986)</td>
<td>Cobb-Douglas</td>
<td>Sales</td>
<td>Selling space</td>
<td>K_{selling} = 0.66</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Nonselling space</td>
<td>Constrained to 0.34</td>
</tr>
<tr>
<td>Ratchford and Stoops (1988)</td>
<td>Ehrlich Fisher Time-Series</td>
<td>Quantity sold</td>
<td>Labor hours</td>
<td>L = 0.00 to 0.27</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Shelf Space</td>
<td>K = 0.05 to 1.33</td>
</tr>
<tr>
<td>Ratchford and Stoops (1992)</td>
<td>Ehrlich Fisher Time-Series</td>
<td>Sales deflated</td>
<td>Advertising</td>
<td>-0.0212</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Wages</td>
<td>-0.6240</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hrs/month</td>
<td>L = 0.3171</td>
</tr>
</tbody>
</table>
Efficiency of Factor Utilization in Retailing

Several authors examine the utilization of production factors in retailing by studying the marginal productivity of factors and the returns to scale. Researchers hypothesize that efficient firms will pay the factors of production an amount equal to their marginal output (Lusch 1980) and operate at constant returns to scale (Ingene 1984). These ideas are accepted to such a degree that they are periodically incorporated as assumptions into research (Ratchford and Brown 1985; Ratchford and Stoops 1992). However, the evidence suggests the need to further explore the efficiency of retail firms.

Marginal Productivity

Lusch (1980) examines the marginal productivity of food wholesalers. Through the use of a Cobb-Douglas production function, he finds that these firms tend to operate at high levels of economic efficiency. Unfortunately, the same examination has not been completed for the retail industry.

Economies of Scale

Larger establishments tend to be more efficient due to specialized equipment, specialization of labor, and superior organization and administration (Arndt and Olsen
1975). Good (1984) refers to specialization effects as "real" economies of scale. He also identifies a class of scale economies called "pecuniary," which is identified as decreasing costs due to improved market position.

Most studies indicate a point at which increasing returns to scale change to diseconomies due to a U-shaped cost curve. At some point a company is expected to have greater costs per unit as the number of units increase. Arndt and Olsen (1975) suggest that this may be due to difficulties in managing large enterprises.

Tucker (1972), Hall, Knapp, and Winsten (1961), and Ingene (1984) argue that in long-run equilibrium only constant returns to scale will be observed. If increasing returns to scale exist, competition will force store size to increase in order to take advantage of scale efficiencies. Also, if firms operate at diseconomies, competition will force them to downsize or go out of business.

Several authors argue that non-constant returns can exist over relatively long periods of time. Theory suggests that the limited divisibility of production factors justifies increasing returns to scale. Ingene (1984) contends that stores lack the ability to downsize quickly due to the durability of capital. He also identifies difficulties of increasing store size in the short term. Other authors indicate that increasing returns to scale may be due to specialized factors that cannot readily be bought on the open market (Arndt and Olsen 1975), uncertain demand levels (Ofer 1973), and the multi-product nature of retailing (Panzer and Willig 1977). Conversely, persistent diseconomies of scale may exist due to rapid declines in consumer spending or increased competition (Ingene 1984).
### TABLE 2.3

**RETURNS TO SCALE STUDIES**

<table>
<thead>
<tr>
<th>REFERENCE</th>
<th>TYPES OF MEASURES</th>
<th>STORE TYPES</th>
<th>RESULTS PASSUS COEFFICIENT</th>
<th>STAT TEST FOR SCALE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tilley and Hicks (1970)</td>
<td>Descriptive</td>
<td>Food Stores</td>
<td>Returns to scale may be exhausted</td>
<td>None given</td>
</tr>
<tr>
<td>Ofer (1973)</td>
<td>Output-value added</td>
<td>Food, Apparel</td>
<td>Not available</td>
<td>Increasing RTS</td>
</tr>
<tr>
<td></td>
<td>Inputs - physical &amp;</td>
<td></td>
<td></td>
<td>Increasing RTS</td>
</tr>
<tr>
<td></td>
<td>$ inventory</td>
<td>Furniture</td>
<td></td>
<td>Increasing RTS</td>
</tr>
<tr>
<td>Arndt and Olsen (1975)</td>
<td>Output- gross profit</td>
<td>Selfservice &amp;</td>
<td>1.42, 1.23, 0.98, 0.89,</td>
<td>None given</td>
</tr>
<tr>
<td></td>
<td>Inputs - physical</td>
<td>Manual</td>
<td>1.11</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Supermarkets</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White (1976)</td>
<td>Output-value added</td>
<td>Department stores</td>
<td>N/A</td>
<td>Increasing RTS</td>
</tr>
<tr>
<td></td>
<td>Input - operation figures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lusch and Ingene (1979)</td>
<td>Output - sales, value added,</td>
<td>Floor covering</td>
<td>Monetary inputs 0.863 to 0.942 to 0.942</td>
<td>All eight tests show Constant</td>
</tr>
<tr>
<td></td>
<td>units, transactions</td>
<td>stores</td>
<td>Physical inputs 1.058 to 1.116</td>
<td>Returns to Scale</td>
</tr>
<tr>
<td></td>
<td>Inputs - physical &amp;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>monetary</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lusch (1980)</td>
<td>Output-value added</td>
<td>Food Wholesale</td>
<td>1.058</td>
<td>Constant scale</td>
</tr>
<tr>
<td></td>
<td>Inputs - monetary</td>
<td></td>
<td></td>
<td>t = 0.37</td>
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</table>
### TABLE 2.3 (continued)

<table>
<thead>
<tr>
<th>REFERENCE</th>
<th>TYPES OF MEASURES</th>
<th>STORE TYPES</th>
<th>RESULTS</th>
<th>STAT TEST FOR SCALE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Output - sales</td>
<td>Grocery</td>
<td>1.044</td>
<td>Constant Returns</td>
</tr>
<tr>
<td></td>
<td>Inputs - physical</td>
<td>Department</td>
<td>1.000</td>
<td>Constant Returns</td>
</tr>
<tr>
<td>Ingene (1984)</td>
<td>Apparel</td>
<td></td>
<td>0.890</td>
<td>Diseconomies</td>
</tr>
<tr>
<td></td>
<td>Furniture</td>
<td></td>
<td>0.987</td>
<td>Constant Returns</td>
</tr>
<tr>
<td></td>
<td>Drug</td>
<td></td>
<td>0.876</td>
<td>Constant Returns</td>
</tr>
<tr>
<td></td>
<td>Restaurant</td>
<td></td>
<td>1.131</td>
<td>Increase Returns</td>
</tr>
<tr>
<td>NOTE: Split sample</td>
<td>Fast Food</td>
<td></td>
<td>0.722</td>
<td>Diseconomies</td>
</tr>
<tr>
<td>results not in this table</td>
<td>General</td>
<td></td>
<td>0.992</td>
<td>Constant Returns</td>
</tr>
<tr>
<td></td>
<td>Variety</td>
<td></td>
<td>0.976</td>
<td>Constant Returns</td>
</tr>
<tr>
<td>Good (1984)</td>
<td>Hardware</td>
<td></td>
<td>1.051</td>
<td>Constant Returns</td>
</tr>
<tr>
<td></td>
<td>Sporting</td>
<td></td>
<td>0.901</td>
<td>Constant Returns</td>
</tr>
<tr>
<td></td>
<td>Cafeteria</td>
<td></td>
<td>0.858</td>
<td>Diseconomies</td>
</tr>
<tr>
<td></td>
<td>Output-value added</td>
<td>Grocery stores</td>
<td>N/A</td>
<td>Increasing Returns</td>
</tr>
<tr>
<td></td>
<td>Inputs - physical</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dought (1984)</td>
<td>Output-value added</td>
<td>Fast food</td>
<td>1.09</td>
<td>None given</td>
</tr>
<tr>
<td></td>
<td>Inputs - physical</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thurik and Kooiman (1986)</td>
<td>Outputs - sales</td>
<td>Supermarkets and Superette</td>
<td>0.87</td>
<td>Diseconomies</td>
</tr>
<tr>
<td></td>
<td>Inputs - floor space</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ratchford and Stoops (1988)</td>
<td>Outputs - sales</td>
<td>Book and Office supply</td>
<td>Log-lin = 1.29</td>
<td>None given</td>
</tr>
<tr>
<td></td>
<td>Inputs - physical</td>
<td></td>
<td></td>
<td>Translog = -0.55 to 2.22</td>
</tr>
</tbody>
</table>
As Lusch and Ingene (1979) suggest, non-constant returns to scale should exist only in a non-competitive environment. In general, retailing lacks barriers to competition. Firms have few entry or exit barriers and in the United States they face one of the most saturated markets in the world. This forces competitive retailers to operate at high levels of efficiently, leading to the existence of constant returns to scale. Table 2.3 illustrates the findings of selected studies that have measured and/or tested economies of scale in retailing.

The results of these studies suggest that the efficiencies achieved by retailers depend on the specific industry in which they compete, the time period of the study, and the relative size of the stores in the sample. Seventeen out of 27 statistical tests demonstrate constant returns to scale, with only four indicating diseconomies. This demonstrates that most retailers normally operate at efficient levels, with some retailers still having the ability to increase efficiency through expansion.

Authors also indicate that returns to scale may be a function of the type of measures. Lusch and Ingene (1979) further examine this issue by using both monetary (rent, payroll, sales, value added) and physical (square footage, number of employees, units sold, and transactions) measures of inputs and output. They show that the results of the scale tests do not differ in response to various measures with the exception of transactions, which performs relatively poorly. Also, they recommend using physical units as inputs and value added as a measure of output due to marginal improvements in the robustness of the results (Lusch and Ingene 1979).
While the market efficiency of labor and capital in the retail production has been tested by examining economies of scale, the same is not true for information technology. Yet some publications imply that the reason for the lack of correlation between information technology and labor is that retailers are not efficiently utilizing this input. Also, this stream of research fails to examine the efficiency of factor markets from other points of view. While Lusch (1980) examined marginal productivity of food wholesalers, the same test has not been applied to retailing.

Measurement Issues

The issue of measurement of productivity in retailing is not limited to the examination of scale economies. Brynjolfsson (1993) states that:

After reviewing and assessing the research to date, it appears that the shortfall of IT productivity is as much due to deficiencies in the measurement and methodological tool kit as to mismanagement by developers and users of IT.

Two major areas of discourse have taken place with regard to the measurement of productivity in retailing. First, several authors question the functional form used to examine this issue (Archabal, Heineke and McIntyre 1984, 1985). Other authors question the validity of measures of both inputs and outputs (Lusch and Ingene 1979; Archabal, Heineke, and McIntyre 1984, 1985; Goodman 1985).
Functional Form

Previous studies examine productivity issues with labor productivity as the dependent variable or using a modification of the production function concept. Studies that use labor productivity as the dependent variable tend to test the effects of structural issues on labor productivity (Hall, Knapp, and Winsten 1961; George 1966; Schwartzman 1971; Bucklin 1978; Ingene 1982; Nooteboom 1983; Ingene 1985). While useful to identify correlates of labor productivity, this type of analysis is inappropriate for the examination of the productivity of specific input factors. For estimation of specific productive factors, authors use an adaption of the production function concept.

A production function is defined as a mathematical equation that expresses the relationship between the quantities of variable inputs employed and the quantity of output produced. There are two major classes of production functions: Constant Elasticity of Substitution (CES) (Henderson and Quandt 1986) and Transcendental Logarithmic (translog) functions (Christensen, Jorgenson, and Lau 1973; Brown, Caves, and Christensen 1979).

Ratchford and Stoops (1988) compare a log-linear function and a translog function using a modified Ehrlich-Fisher model. They conclude that the translog function performs better in a time series analysis, although they question some of the results estimated by the translog function.
The most popular functional form in both the marketing and economics literature is a modified Cobb-Douglas (Arndt and Olsen 1975; Ingene and Lusch 1979; Lusch 1980; Ingene 1984; Doutt 1984; Thurik and Kooiman 1986). The traditional Cobb-Douglas production function is expressed mathematically as:

\[(2.1) \quad \text{Output} \ (Q) = (\text{Capital}^p)(\text{Labor}^{(1-p)})\]

The original Cobb-Douglas function is a subset of the CES class of production functions which can be expressed as:

\[(2.2) \quad \text{Output} \ (Q) = A[a-(\text{Capital})^p + (1-a)(\text{Labor}^p)]^{-1/p}\]

CES functions are restricted to be homogeneous to the degree one. In other words, these functions assume that markets are efficient and that firms operate at constant returns to scale. This is one of the reasons that some authors prefer to use a translog function (Ratchford and Stoops 1988), as shown below.

\[(2.3) \quad \text{Output} \ (Q) = \beta_0 (\text{Capital}^b_1)(\text{Labor}^b_2) e^{b_3(L) + b_4(K)}\]

However the assumption of constant elasticity (i.e. homogeneity of degree one) can be relaxed in the modified Cobb-Douglas function by relaxing the constraint on the second coefficient resulting in:

\[(2.4) \quad \text{Output} \ (Q) = (\text{Capital}^{b_1})(\text{Labor}^{b_2})\]

This function allows the coefficients to be estimated independently (i.e. without relational restrictions). For this reason it has enjoyed widespread use in the retailing literature.
Output Measures

Perhaps no issue in the area of productivity estimation is as controversial as the choice of retail output measures. The production function was originally used to measure the productivity of manufacturing. Economists use physical units to measure both inputs and outputs of the production process. However, since retailing is a service industry, output is intangible in nature. Retail output is defined in terms of the added value to the customer in the form of place, possession, and time utility. This lack of physical output generates a great deal of debate (Bucklin 1978; Mark 1982; Archabal, Heineke and McIntyre 1984; Hughs and Serpkenci 1985; Goodman 1985; Archabal, Heineke and McIntyre 1985).

Gross Sales. Ingene (1982) suggests that the proper measure of output is gross sales. Also, a survey of executives reported that the predominant measure of output is inflation adjusted sales (Archabal, Heineke and McIntyre 1984). Because of its availability, gross sales as an output measure receives wide popularity in the literature (Tilley and Hicks 1970; Takeuchi and Bucklin 1977; Ingene and Lusch 1981; Ingene 1982, 1984, 1985; Mark 1982; Nooteboom 1983; Good 1984). In later research, sales has been used only when other measures are unavailable. This is due to arguments that gross sales also includes the value of each member higher in the channel, including manufacturers and wholesalers (Ingene 1985). However, as Marion et al. (1979) indicate, sales and value added measures are nearly monotonic and therefore substitutable for econometric analysis.
**Number of Transactions.** The number of transactions is not widely adopted as a measure of retail output. However, a few authors suggest it as a possible measure (Bucklin 1978; Thurik and Van der Wijst 1984; Thurik 1986). The advantage of using the number of transactions is that it allows for a representation of the physical output of retailing. Lusch and Ingene (1979) argue that it represents a potential measure because:

Marketing has been defined as those activities that are necessary to bring about exchange transactions. Since retailing is a marketing institution one might conclude that the output of retailing is the creation of exchanges (transactions).

They also examine the shortcomings of transactions as a measure of output.

Ingene (1984) and Lusch and Ingene (1979) question the conceptual validity of using transactions as an output measure because it fails to capture value differences due to deviations in transaction size. The limited empirical results indicate that it performs relatively poorly compared to other measures (Lusch and Ingene 1979).

**Value Added.** Value added as an output measure was first proposed by Cox, Goodman, and Fichandler (1965). Many authors suggest value added is the best measure for retail output (Lusch 1980; Ingene 1982, 1984; Doutt 1984; Good 1984; Lusch and Moon 1984; Ratchford and Brown 1985). Value added allows the individual contribution of the retailer to be measured without including the value produced by other channel members.
Summary of Output Measures

In 1948, Cox indicated that:

There can be no one best method of measuring productivity. The best method will vary with ... the purpose of the researcher.

This sentiment is echoed by other researchers, such as Marks (1971, p.7) and Ingene (1982, p. 77).

Archabal, Heineke and McIntyre (1984 1985) sharply criticize all existing measures of retail output. Their premise is that output should not reflect variations in market demand. In general, only a few authors such as Ratchford and Stoops (1988 1992) address this issue by including demand equations in their analysis. Other authors, such as Goodman (1985), argue that since the output of retailing is consumer utility, values are proper reflections of output. In general, researchers either ignore the demand issue or implicitly assume that production in retailing is endogenous to the retailer. This assumption is valid if all retailers in the sample face the same environmental conditions. Further, Thurik and Van der Wijst (1984) suggest that part-time labor is used to meet fluctuations in demand.

Empirical results show that nearly all measures of retailing output produce equivalent results (Lusch and Ingene 1979; Good 1984, p.88). However, due to conceptual problems with both gross sales and the number of transactions, most researchers accept value added as the best measure of retail output (Lusch 1980; Lusch and Moon 1984; Doutt 1984; Good 1984; Ingene 1984; Ratchford and Brown 1985).
Input Measures

Measures of retail inputs are subject to nearly as much controversy as measures of output. Researchers generally agree that retailers use at least two factors of production to create output: capital and labor.

**Capital.** Retail capital is measured as either the square footage of space or dollar value of assets. The most common measure of retail capital is floor space (Tilley and Hicks 1970; Arndt and Olsen 1975; Lusch and Ingene 1979; Ingene 1982 1984 1985; Lusch and Moon 1984; Good 1984; Thurik and Kooiman 1986). A few researchers use monetary values to represent retail capital (White 1976). Doutt (1984) uses the insured value of the establishment. In their comparative study, Lusch and Ingene (1979) use the total value of retail assets. They suggest that while the use of square feet as a measure of capital is more predictive, both measures are adequate.

Ratchford and Stoops (1988) provide one of the few research efforts to deviate from these measures by using shelf space instead of floor space. Although arguably a better measure, it is rarely available to a researcher on a large scale. Ratchford and Stoops (1988) were able to use shelf space by limiting their sample to nine stores.

**Labor.** The amount of labor used by a retailer to create output is measured as either number of employees or the amount of money paid to employees. The total number of employees or full-time equivalent (FTE) employees is the most common measure of labor (Hall, Knapp, and Winsten 1961; George 1966; Schwartzman 1971; Arndt and Olsen 1975; Bucklin 1978; Lusch and Ingene 1979; Ingene 1982, 1984;
Lusch and Moon (1984). The number of hours worked is also widely adopted (Thurik and Van der Wijst 1984; Doutt 1984; Good 1984; Ratchford and Stoops 1988, 1992). These two measures are monotonically related since FTE employees divided by 40 is equivalent to hours of labor.

The total wage bill of employees is used to measure the amount of labor by Lusch (1980) and Lusch and Ingene (1979). Conceptually, this adjusts for differential ability of employees, such as differences between managers and salespeople. Ratchford and Stoops (1992) suggest that relative wages are related to productivity differentials. This logically suggests that payroll may provide a better measure of labor usage.

Other Factors of Production

While labor and capital are the most commonly used factors, a few authors have suggested others. Doutt (1984) includes measures of customer capacity and type of ownership as potential factors, neither of which was significant in his analysis. Ownership type is examined by Lusch and Moon (1984) as well, who found a significant relationship with labor productivity. Ofer (1973) uses inventory value as an input when testing economies of scale. Ratchford and Stoops (1992) examine the productivity of advertising, the effect of which was estimated to be negative. The literature reveals that few authors deviate from the traditional measures of labor and capital.
A potential productive factor that is overlooked when estimating retail productivity is information technology (Weber 1990; Archabal and McIntyre 1987). Some authors include it in the capital variable by default (Lusch and Moon 1984; Doutt 1984). However, this does not allow for the separation of the contribution of capital in the form of retail space and information in the form of technology. Good (1984) and Weber (1990) attempt to include information technology in the production process. They use either semantic differential scales or percentages of usage to measure information technology. Their findings indicate that retailers perform better with greater degrees of technology. Unfortunately, these methods do not allow the researchers to accurately estimate the contribution of information technology to retail productivity.

Information Technology and Retail Productivity

Authors are nearly unanimous in their agreement that information technology is theoretically related to gains in retail productivity. Information technology is expected to create a competitive advantage (Porter and Millar 1986; Harrison 1991) and increase the efficiency of labor (Ingene 1984), retail space (Robins 1993), and inventory investment (Ofer 1973). Porter and Millar (1986) state that information technology can create a competitive advantage because of its ability to alter industry structure, support cost and differentiation strategies, and spawn new businesses.
Most researchers would argue that information technology should theoretically increase retail productivity. However, there exist opposing convictions about whether this is true in reality. Authors who question productivity gains from information technology point to the lack of gains during periods of high investment. These authors point to a Bureau of Labor Statistics study indicating slow productivity growth during periods of high investment in information technology (e.g., Krohe 1993; Davis 1991; Keyes 1990).

Authors supporting continued investment in information technology cite that previous research fails to uncover actual gains in productivity. The lack of discovery of gains is rationalized in several different ways. Among these are the failure of measurement instruments (Metcalf 1992); inability to account for gains in the quality of services (Rudd 1993); misuse of technology (Manzi 1992); failure to provide structures and processes that facilitate the use of information technology (Loveman 1991); failure to completely integrate the technology and the firm (Schnitt 1993); and the lack of management involvement (Davis 1991). However, to date there are no scientific studies which examine these issues, although there have been calls for such research (Archabal and McIntyre 1987).
Specific Types of Information Technology

An examination of the literature reveals 19 specific types of information technology that have the potential to increase retail productivity: Universal Product Code (UPC) scanners, electronic cash registers, electronic credit card approval systems, electronic check approval devices, facsimile (fax) machines, barcode printers, computer terminals, laptop computers, desktop/personal computers (PCs), computer printers, specialized software, electronic mail (E-mail), Point-Of-Sale (POS) systems, Management Information Systems (MIS), computerized accounting and bookkeeping systems, Electronic Data Interchange (EDI) systems, Quick Response (QR) systems, computerized inventory tracking systems, and computerized buying/ordering systems.

UPC Scanners

A UPC scanner is defined as any mechanical device that has the ability to read a product barcode. The advent of UPC scanner technology is identified as a major influence in increasing efficiency and productivity for retail institutions (Kennedy 1991). Stamper (1992) identifies the retail industry as a model of how bar code scanning can be used to improve productivity.
Mayson, Mayer, and Ezell (1994, p. 121) state that:

UPC scanner and price marking systems offer the following benefits:

1. Improved accuracy.

2. Improved customer satisfaction. Speed, accuracy, quietness, and the detailed receipt are customer pluses.

3. Time and labor savings. Some stores report productivity gains of up to 45 percent when item-price marking is eliminated.

4. Improved inventory and financial control.

Scanners effectively contribute to retail productivity in five major ways. First, scanning technology decreases the time it takes to check-in inventory (Rouland 1992; Connolly 1993). Second, retailers that use scanners do not have to price each individual item. Also, changing prices is easier for the same reason. This allows retailers to use shelf pricing systems. Third, retailers are able to take inventory more quickly and accurately than with traditional paper-based systems. Fourth, retailers are able to improve customer service by improving checker accuracy and speed. Lastly, data collected from store scanners is used for research purposes (O’Conner 1991; Taylor 1990). A survey conducted by Touche Retail Systems Groups indicates that retailers cite price accuracy, checkout productivity, and unit inventory accuracy as the three most important benefits of scanning (*Chain Store Age Executive* 1989).

Advances in scanner technology have continued over the last decade. Scanners are now capable of reading a barcode correctly on the first pass at least 90 percent of
the time (Schlossberg 1992). Also, scanners are taking on new forms, such as hand
held scanners by Telxon and Symbol Technologies and pen scanners by Telxon and
Stylus Concepts (Robins 1993).

Barcode Printers

Barcode printers are defined as any machine that has the ability to print a
product barcode (UPC or store barcode). Barcode printers include items such as meat
and deli scales that have the ability to print barcodes. These printers are expected to
improve productivity by allowing the use of scanners on products that do not have a
preprinted UPC or barcode (e.g. custom orders, meat, deli, and bakery items). Also,
retailers that have the ability to print barcodes can take corrective action when
problems arise reading manufacturer barcodes (Pierce 1990).

In 1989, Ames Department Stores made an investment in continuous laser
printers to produce its tags and labels. Since then, labor costs have been halved. The
payback time for the system was 7.5 months, based on gross savings in labor and
materials. Total savings is expected to exceed $200,000 a year (Chain Store Age
1990).
Electronic Cash Registers

Electronic cash registers are the heart of a Point-of-Sale (POS) system. For many small retailers, they are a close substitute for a full POS system. It is expected that electronic cash registers assist retailers by improving the accuracy and speed with which checkers can assist customers. Electronic cash registers also increase the efficiency of cashiers by providing information such as the amount of change due a customer. Electronic cash registers are also an integral part of POS systems.

Credit Card and Check Approval Systems

Retailers and banks have devised various systems to deal with the increasing number of bad checks and stolen credit cards. Original systems dealt with credit card fraud by periodically printing a booklet of stolen and revoked credit card numbers. This did not overcome problems of over-limit and recently stolen credit cards. Some retailers dealt with checks in a similar fashion. Both of these systems were time consuming for the checker and inaccurate in the time lag during printing and distribution of the booklet.

Retailers are now using electronic communication with banks and credit card companies to increase efficiency. Devices that permit direct communication allow retailers to reduce salesclerk time and increase payment for sales. Connelly (1988), among others, suggests that automating the credit card draft process at the point of sale
offers cost and productivity benefits to both retailers and banks. Also, retailers save resources because they are not usually required to submit paper drafts to the bank. Daly (1993) indicates that smaller retailers are able to avoid the expense of third-party companies by moving their credit card operations in-house. Several other authors also tout the advantages of these systems (Robins 1988; Allen and McCarthy 1987).

Fax Machines

Communication of documents often takes several days using traditional means (i.e. United States Postal Service mail). Even fast delivery of documents takes nearly 24 hours. Waiting for delivery of documents; such as invoices, orders, corrections, price quotes, and other information; between retailer and vendor can delay operations for the retailer.

When Payless Cashways introduced Fax and phone orders, sales to professionals nearly doubled (Palmeri 1993). Other companies such as Avon products have started taking orders via fax (Sloan 1993). Still other companies, such as Redbook, are now using fax machines to provide information on retail store sales nationwide (Epstein 1993). Some retailers, including Sears and Fingerhut, are providing promotional messages and faxed ordering information on catalogs, Christmas gift ideas, and weekly sale specials using a fax machine (Catalog Age 1991). Fax machines are also used, mainly in the health care and pharmacy industries, to transmit information to third party payers, which increases efficiency (Perrin 1990).
Perhaps the largest impact of the fax machine on retail productivity is in the catalog industry. It is estimated that fax orders accounted for 14 to 15 percent of all business catalog orders in 1991 (Poirier 1992). Catalog ordering by fax has continued to increase over the last few years (Dowling 1993). In some cases, a company's computers can receive a faxed order, scan the order, and process it without human intervention (Poirier 1993).

Many retailers increase the efficiency of the communication process by using fax machines. These allow the delivery of documents in a relatively short period of time. This allows retailers to have timely information and make more informed decisions. It also shortens the lead time for inventory.

Computer Hardware

Three distinctions can be made with regard to computer hardware: desktop/personal computers (PCs), laptop computers, and computer terminals. Computers are the brains behind any information system. They allow the storage, retrieval, transmission, and manipulation of data for virtually every part of retailing.

Friedman (1988) argues that computers have had a definite impact on the growing productivity in retailing. However, these gains are no longer reserved for retailers that can afford multi-million dollar investments in technology. Small retailers can now gather, process, transmit, and analyze information with the same thoroughness, speed, and accuracy as larger retailers (Parker and McKinney 1993).
Allaway, Mason, and Moore (1988) suggest that smaller retailers can benefit by using PCs for strategic planning and improvement of the day-to-day productivity of the retailing mix variables.

Laptop computers increase employee efficiency when they are unable to access a personal computer or terminal. Several retailers have already identified gains attributed to laptop computers. Calder, a discount chain, has reduced the paperwork of softline buyers by 5000 hours per year (Fox 1992). Also, Shoppers Drug Mart, one of Canada's leading retailers, attributes increases in the efficiency of its sales force to the availability of laptop computers (Heeney 1992).

Specialized Software

There are numerous software programs available to the retailer. These can range from those that are mass-marketed programs, such as Lotus 1-2-3, to very specialized packages that are designed specifically for a single retailer. These software programs save both management and salesperson time in computing needed information. Schwartz (1993, p.76) argues that "software is the key to making information technology accessible and businesses more productive."

Programs such as Kronos' Timekeeper Central (Ain 1993) and SMILE (Hennessy 1993) assist stores in developing budget and staffing parameters and accurate application of pay rules. Fearnely (1993) suggests that these systems can produce schedules in a fraction of the time it takes managers to do it manually. Kroger
estimates that it saves $20,593 per week using an automated scheduling system (Hennessy 1993).

Specialized software programs increase productivity by tracking gift certificates (Chain Store Executive Age 1993); improving payments to the retailer (Davis 1993); increasing merchandising effectiveness (McCready 1991); reducing paperwork (James 1993); improving inventory tracking (Giuliano 1993); increasing space efficiency (Robins 1993; Garry 1992; Rouland 1992); and many other advantages.

**POS systems**

Electronic Point-Of-Sale (POS) systems are defined as those systems that record, accumulate, and convey consumer purchase information at the point of sale. Many retailers believe that implementing POS systems can easily cost-justify purchases (Allen and McCarthey 1987; Zimmerman 1988). The trade literature provides several case studies that indicate POS systems increase labor productivity through ease of price checking (Robbins 1988; Zimmerman 1988; O’Quinn 1986) and speeding checkout times (Robbins 1988; Hoover 1986). It has also been suggested that POS system increase capital productivity through increasing inventory turnover (O’Quinn 1986) and better inventory control (Robbins 1988; Zimmerman 1988; O’Quinn 1986; Hoover 1986).
Electronic Data Interchange

Electronic Data Interchange (EDI) is defined as a system that enables retailers to send and access information with vendors electronically. These systems allow information and paperwork to be transferred from a company computer to a separate company's computer without human intervention.

A Meretrends report indicates that the benefits of EDI include: 1) saving a week or more between customer purchases and back-in-stock in the store; 2) reorderable merchandise can be handled through automation. Buyers will be able to concentrate on trends, product differentiation by store, and better planning of the business; 3) retailers will be better equipped to work with vendors by sharing consumers' desires directly; 4) reducing inventory levels by 22 to 65 percent; 5) fewer returns to vendors; and 6) payroll savings from reduced mail sorting, keypunch activities, auditing paperwork and elimination of handling packing slips, freight bills, and invoices (Weber 1990).

Electronic Mail (E-mail)

E-mail systems allow retailers to communicate and send documents to vendors or manufacturers in real time. This decreases the response delay during delivery and therefore increases the retailers' productivity. Also, e-mail systems are often used in conjunction with EDI to improve retailer productivity (Marion 1992).
Other Information Systems

The literature cites several systems that are made up of both hardware and software components that perform specific functions. However, these systems are usually treated separately from their subcomponents. These include Management Information Systems (MIS), Accounting systems, Quick Response (QR) systems, inventory tracking systems, and buying/ordering systems.

MIS are defined as computerized systems that provide management with operational information with the intent of providing a basis for managerial decision making. Accounting/bookkeeping systems are electronic systems that functionally assist or replace traditional bookkeepers and/or accountants in maintaining and developing ledgers and financial statements. A QR system is defined as an electronic, computerized system that allows retailers to order, check, and invoice inventory. These are often used in conjunction with EDI systems to improve inventory control. Inventory tracking systems maintain a constant indicator of the level and value of inventory in the store. A computerized buying/ordering system is defined as a system designed to assist in the buying and ordering of inventory, including estimating order quantities and completing purchase orders.
Chapter Summary

The history of productivity in marketing extends back to Cox (1948). Over the last two decades this area has generated a great deal of controversy regarding the proper techniques of analysis and interpretation of results. However, it is clear that there exists a deficiency and need for further examination of retail productivity issues as they relate to information technology. While several case studies indicate that information technology contributes positively to the retail firm, this issue has yet to be studied or tested using scientific methods and procedures.

Chapter III develops formal research questions and specific hypotheses that address the apparent gaps in the existing literature. These questions are then put in a theoretical framework from which an appropriate methodology for testing is developed. The results of these tests are presented in Chapter IV with a discussion in the final chapter.
CHAPTER III

RESEARCH DESIGN

This chapter includes a statement of the research problem, specific research questions, a discussion of the conceptual framework of the study, and the underlying theoretical foundations. Four sets of specific hypotheses are developed from the research questions. The sample frame and sampling procedure is presented followed by a discussion of the measures used in this research and the research instrument. Finally, the statistical analysis is discussed in detail, focusing on the functional form, the various models to be estimated, and specific tests for each hypothesis.

Research Question Development

A review of the literature in Chapter II shows that there are several areas that have not been examined regarding productivity in retailing. Opposing opinions have been expressed about the productivity of information technology. However, there is an absence of formal research to define or measure the contribution, or lack thereof, of information technology to retailing. The following research questions are developed to assist in filling the gaps in the current literature.
Productivity of Information Technology

As discussed in Chapters I and II, researchers have argued that information technology has not contributed to productivity in retailing. These authors point to figures from the Bureau of Labor Statistics indicating slow productivity growth during periods of high investment in information technology (e.g., Diebold 1990; Keyes 1990; Davis 1991; Levy 1993; Labbe 1993; Krohe 1993).

Other authors continue to support investment in information technology to improve productivity (Davis 1991; Loveman 1991; Manzi 1992; Metcalf 1992; Rudd 1993; Schnitt 1993). A third group addresses the potential for productivity gains from a theoretical view (Porter and Millar 1986; Harrison 1991). In general authors suggest that information technology should increase productivity through increasing either labor efficiency or space utilization.

Testing the productivity of information technology, or lack thereof, is the major focus of this research. The first research question deals with this issue.

Research Question 1:

Does information technology contribute to the productivity of retail institutions?
Market Efficiency

As stated earlier, one possible explanation for the suggestion that purchases of information technology are not productive is that the market for information technology is inefficient. Three major market inefficiencies may exist. First, retailers could be substituting information technology for cheaper inputs such as capital or labor. This would result in retailers having higher costs than necessary at any given level of output. Second, retailers could be paying an excessive price relative to the gain from information technology. Lastly, retailers could simply be purchasing more information technology than is warranted. None of these propositions have been empirically tested. Thus the question remains:

Research Question 2:

Is the market efficient in allocating information technology?

Effect of Technology on Labor and Capital

Information technology purportedly increases labor efficiency through either decreasing the amount of labor needed for a given task or increasing the units of output for a given amount of labor. This is accomplished by more efficient management of employees or by increasing the speed and accuracy of employees performing a given task. For example, scanners have dramatically improved both the accuracy and speed with which checkers can price purchases (Mason, Mayer, and Ezell 1994, p.121).
Information technology purportedly increases capital productivity by increasing space efficiency. Abbott (1992) indicates that retailers such as British-based Tesco have used information technology to reduce stock levels, reduce the risk of goods perishing on the shelf, and cut warehouse running costs. D'Angelo (1990) suggests that information technology can also increase productivity by simplifying the supervision of inventory and making space allocation and floor layout more efficient.

While several publications imply a substitution effect of information technology for both capital and labor, there are no empirical studies of whether or to what extent this substitution effect actually exists. Thus it is important that the following question be addressed:

Research Question 3:

To what degree can information technology be substituted for labor and/or capital in retailing?

Conceptual Framework

The contribution of information technology to retail productivity and the efficiency with which it is allocated is examined within the framework of a production function. A production function examines the contribution of factors of production in creating output. The literature recognizes six factors of production: natural resources, land, labor, capital, technology, and energy. Only two of these have been examined
thoroughly in the context of retail productivity: capital and labor. One possible reason for this is that retailing is not land, natural resource, or energy intensive.

The production function concept states that factors of production are combined to produce output for the firm.

Figure 3.1 shows a conceptual model of the production function. In this figure, three factors of production, labor, capital and information technology are combined to create output. These are the factors that are examined in the study.

Theory of the Firm

The concept of the production function is derived from the Theory of the Firm from economics. The Theory of the Firm includes three basic propositions. First, a firm is a technical unit which produces commodities. Its entrepreneur decides how much of a commodity to produce. Second, the entrepreneur transforms input factors; such as labor, capital, land, natural resources, and technology; into output based on technical rules specified by their production function. An input is any good, service, or resource which contributes to the production of outputs. Third, the entrepreneur
gains the profits or suffers the losses which result from the difference between the cost of the inputs and the revenues from selling outputs (Henderson and Quandt 1986).

The traditional Theory of the Firm must be modified slightly to fit the subject of this research. Retailing is a service, and therefore each unit of production is heterogeneous (Parasuraman and Varadarajan 1988; Fryer 1991). This contrasts with the Theory of the Firm, which assumes production of homogeneous commodities. Therefore output of the retailer is discussed as units of utility, measured in dollars. Potential problems with this are discussed further in the measurement section below.

Production Function

A production function is defined as a mathematical equation that expresses the relationship between the quantities of variable inputs employed and the quantity of output produced. As is implicit in other discussions of production functions, the assumption of a single continuous function with continuous first- and second-order partial derivatives is adopted (Henderson and Quandt 1986). Also, for statistical simplicity, it is assumed that the retail production function is regular strictly quasi-concave and is defined only for non-negative levels of inputs and outputs (Henderson and Quandt 1986). Other assumptions implicit in the use of a production function are further examined in the next section.

As discussed in Chapter Two, production functions can exist in several different functional forms. The most popular functional form in both the marketing and
economics literature is a modified Cobb-Douglas. The traditional Cobb-Douglas production function is expressed mathematically in Equation 3.1.

\[
(3.1) \quad \text{Output} = (\text{Capital}^\beta)(\text{Labor}^{1-\beta})
\]

The original Cobb-Douglas function is restricted to be homogeneous to the degree one. In other words, this function assumes that markets are efficient and that firms operate at unitary Economies of Scale (EOS). The original Cobb-Douglas function is a subset of a class of production functions referred to as Constant Elasticity of Substitution (CES) functions. The broader form for this class is expressed in Equation 3.2.

\[
(3.2) \quad \text{Output} = A[\alpha-(\text{Capital})^\alpha + (1-\alpha)(\text{Labor}^\alpha)]^{1/\alpha}
\]

The assumption of constant elasticity (i.e. homogeneity of degree one) is relaxed in the modified Cobb-Douglas function by removing the constraint on the second coefficient (1-\(\beta_1\)). This takes the mathematical form of Equation 3.3.

\[
(3.3) \quad \text{Output} = (\text{Capital}^{\beta_1})(\text{Labor}^{\beta_2})
\]

This function allows the coefficients to be estimated without relational restrictions. Thus, it does not functionally require that a market be efficient in allocating resources. This function is actually a subset of the transcendental logarithmic (translog) class of production functions, which is shown in equation 3.4, below.

\[
(3.4) \quad \text{Output (Q)} = \beta_0 (\text{Capital}^{\beta_1})(\text{Labor}^{\beta_2}) e^{\beta_3(L) + \beta_4(K)}
\]

The CES functions do not allow for this freedom of estimation. For this reason and its widespread use in the retailing literature, an extension of the translog and the Cobb-Douglas functions are chosen for this research.
Assumptions of Production Functions

Several assumptions are traditionally connected with production functions. These are allocative efficiency, exogenous demand side variables, acceptance of "economic paradigm" of production (Ingene 1984), and that exogenous effects of environmental forces are constant. These need to be examined in more detail before continuing.

Allocative efficiency. The traditional Cobb-Douglas production function assumes that the market will allocate factor inputs efficiently. Mathematically this is expressed by the \((\beta-1)\) constraint on the original Cobb-Douglas function. While this constraint is freed in the translog and modified Cobb-Douglas function, the implicit assumption of allocative efficiency still exists through the assumption that all firms in an industry face the same production function. While it is not assumed that the firms operate in the same manner (i.e. on the same point on the production function), it is assumed that a firm cannot create more of an output than a competing firm using the exact same inputs. One would expect this assumption to hold only for competitive industries. Since retailing is a highly competitive industry, this assumption is not overly burdensome.

Exogenous demand. Production functions assume that firms will create output in a technologically efficient manner, regardless of demand. In other words, firms will not allow factor resources to be unused or used inefficiently, even when demand is low. Instead, managers will adjust factor levels to produce what is desired by the
market. In retailing this is accomplished by adjusting the level of part-time and temporary labor, such as during the holiday season (Thurik and Van der Wijst 1984) or converting non-selling space to selling space (Thurik and Kooiman 1986).

**Economic paradigm.** The theory of the firm also assumes that managers are rational profit maximizers and that information is free and equally available. The first assumption, that of rational profit maximizers, is not a significant constraint with regard to the study. The second assumption of the economic paradigm, perfect information, is relaxed by the very nature of this study. The inclusion of information technology in the production function allows for different levels of access to information between firms. Thus the study assumes and measures an explicit cost of information in the form of information technology.

**Constant exogenous effects.** A production function also assumes that exogenous variables are constant across firms. Exogenous effects, such as laws and economic climate, tend to change dramatically over time and across geographical areas. This study controls for these by utilizing a cross-sectional sample in a single market during a single time period. Thus sample firms face the same environmental constraints and exogenous effects will apply equally to all retailers in the sample.
Marginal Productivity Theory

The marginal product of an input is defined as the rate of change of total product, or total amount of output, with respect to variations in input quantity. This is shown graphically using total product curves, as shown in Figure 3.2. The curves represent the total product for any level of input factors, in this case Capital (K) and Labor (L). Each subsequent total product curve represents a different level of inputs and thus a different level of output than the preceding curve.

The slope of the total product curve is the marginal product at any level of K (Capital) and L (Labor). The marginal product of labor is calculated mathematically as the first partial derivative of the production function with respect to labor, as shown in equation 3.5.

\[(3.5) \quad MP_L = \frac{\partial Q}{\partial L}\]

Likewise, the marginal product of capital can be computed in the same manner:

\[(3.6) \quad MP_K = \frac{\partial Q}{\partial K}\]

According to marginal productivity theory, an entrepreneur will continually use inputs until the cost of the input exceeds the amount it contributes to the firm. The
marginal cost of a factor should be exactly equal to the marginal product (output) of the factor. More labor will be added until the cost of labor climbs to the point where it equals its contribution to output or, more likely, the output contribution declines to the cost of labor. If managers do not add factors that cost less than their contribution, they lose potential profit. On the other hand, if a manager adds too much labor, then the labor will cost more than its output, thus the manager faces a decline in profit.

Rate of Technical Substitution

The Rate of Technical Substitution (RTS) is defined as the rate at which one input factor can be substituted for another without affecting the amount of output produced. This can be shown graphically through an isoquant, a graphical or mathematical depiction of all combinations of input factors that yield a specific output, as shown in Figure 3.3. Each curve on the isoquant represents a higher level of output (Q, Q', and Q''). The RTS of any production function is the ratio of the marginal products, which is the slope of an isoquant at any given level of output.

Since the marginal product is equal to the first partial derivative of
the production function with respect to a given input, the RTS is equal to the ratios of first partial derivatives with respect to inputs. The RTS of capital for labor can be expressed mathematically as:

\[
\text{RTS of } K \text{ for } L = \frac{MP_L}{MP_K} = \frac{(\partial Q/\partial L)}{(\partial Q/\partial K)}
\]

This represents the degree to which one factor (K) can be substituted for another factor (L) while maintaining the same amount of output.

**Economies of Scale**

The term Economies Of Scale (EOS) is synonymous with returns to scale. It describes the responsiveness of output to proportionate increases or decreases of inputs. If a firm is operating at unitary EOS (i.e. constant returns to scale), then any increase in input factors will result in the same increase in output. For example, if input is doubled, then output production is also doubled. At positive economies of scale (i.e. positive returns to scale), a firm obtains a greater proportion of output for any increase in inputs. For the previous example, the firm would produce more than double the amount of output when inputs were doubled. Negative EOS, or diseconomies of scale, exist when the firm produces less than a proportionate increase in output for any increase in inputs.

EOS is most easily defined mathematically by utilizing the concept of the degree of homogeneity of a production function. A production function is homogeneous to degree \(k\) if, when all factors are increased by a constant factor, then output increases
by that factor to the exponent k. In other words, if capital and labor are increased by n times, and output increases by $n^k$ throughout the domain of the production function, then the production function is homogeneous to degree k (Henderson and Quandt 1986). A firm operating at unitary economies of scale has a production function that is homogeneous to degree one. At positive EOS, it is homogeneous to a degree greater than one. For any firm operating at diseconomies of scale, the production function is homogeneous to a degree less than one.

The degree of homogeneity of any production function is determined through the use of a passus coefficient, which is defined mathematically as the sum of the exponential coefficients of input factors in a Cobb-Douglas production function (Arndt and Olsen 1975). A firm operating at unitary economies of scale has a passus coefficient of 1.0, as in the original Cobb-Douglas production function. At positive EOS, it has a passus coefficient of greater than one. Likewise, a firm or industry operating at diseconomies of scale has a passus coefficient of less than one. The most popular CES function is the traditional Cobb-Douglas function (equation 3.1). For this function, the passus coefficient is equal to one ($\beta + (1-\beta)$). Thus the function constrains estimation to unitary economies of scale.

Theory suggests that firms operate on a production function at constant returns to scale (Ingene 1984; Tucker 1972; Hall et al. 1961). While some authors argue that long-run equilibrium is always unitary EOS, there are also counterarguments for the sustainability of non-constant returns (Ingene 1984). These counterarguments largely apply to the inability to change physical characteristics of factor inputs. This research
not only tests this proposition, but also removes constraints by testing the degree of homogeneity.

**Development of Hypotheses**

Technology is defined by economists as "all the technical information about the combination of inputs necessary for the production of output" (Henderson and Quandt 1986, p. 66). In the majority of retailing and economic studies of production functions, technology is assumed to be constant across firms. However, in retailing the degree of technology often differs dramatically between firms (Weber 1990). In general, economists assume that "The production function differs from the technology in that it presupposes technical efficiency...." (Henderson and Quandt 1986, p. 66). In this study this assumption is relaxed to allow differing levels of technical efficiency across retail firms.

Both the logic and case studies supporting increased productivity through the use of information technology are appealing. However, empirical evidence against aggregate productivity gains in the economy is accumulating (Diebold 1990; Keyes 1990; Davis 1991; Levy 1993; Labbe 1993; Krohe 1993). In either case, the productivity, or lack thereof, of information technology is not convincingly established in the literature. A first priority of this study is to examine the overall contribution of information technology as a productive factor in creating output for the retailer. The first hypothesis states:
H1: Information technology has a statistically significant positive effect on the output of retail institutions.

If information technology contributes positively to the output of a retail firm, it is by definition productive. In other words, if information technology can be used in conjunction with other factors of production to create output, it is productive.

Market efficiency

As discussed in Chapters I and II, many scholars and trade journalists indicate that services, and retailing in particular, is not as productive as other industries. This is especially true with regard to the use of information technology. In order for a market to operate in an economically efficient manner, factors of production must be allocated according to cost and output. Hypotheses two, three, and four examine whether information technology is allocated efficiently in the retailing industry.

Economies of Scale. As previously discussed, Economies Of Scale (EOS) is defined as the percentage change in output, relative to a given percentage change in inputs. EOS is equal to one when a doubling of inputs will double outputs.

In an efficient market operating at equilibrium, firms should operate at constant returns to scale (Ingene 1984). If a retailer can obtain more output by increasing inputs, then they should do so. However, if EOS is less than one, then the retailer has employed assets that are not producing output at a constant rate. The second
hypothesis questions whether retailers are operating at long-run equilibrium and optimal efficiency.

H2: Economies of scale (EOS) in retailing is equal to one (i.e. retailers have a production function that is homogeneous to degree one).

Marginal product. Another manner in which to test the efficiency of the market for retail information technology is to examine the cost of the factors of production to the retailer. A retailer should continue to add more units of a factor of production until the marginal cost of the factor exceeds the marginal value derived from adding another unit. The firm should continue to employ resources until diminishing marginal returns exhaust its net marginal value. For example, if a retailer can employ a salesperson for $100 a day and the salesperson produces $150 in net value in a day, it is obvious that they should be employed. This is referred to as the Marginal Productivity Theory. The same theory applies to all productive assets, including information technology. The hypothesis to examine information technology using this theory can be stated as:

H3: Information technology is paid an amount equal to its marginal product.

Rate of technical substitution. Retailers should operate at a point on the production function where one dollar of information technology can be substituted for one dollar of any other factor of production to produce a given level of output. As discussed earlier, the Rate of Technical Substitution (RTS) is the rate at which one factor can be substituted for another while maintaining the same level of output. If inputs and outputs are measured in dollar values and the factor market is efficient, then
the RTS between any two factors of production should be equal to one. Retailers should theoretically operate on the production function at the point where one dollar's worth of one factor can be substituted for a single dollar's worth of any other factor.

If a retailer is operating at any other point on the production function (RTS not equal to one), then they are operating inefficiently. This inefficiency arises because of the availability of a less-cost factor of production that the retailer is not utilizing. For example, if a retailer operates where the RTS between labor and capital is equal to four, then the retailer may substitute one dollar's worth of capital for four dollar's worth of labor and obtain the same output. In this case, the retailer should continuously substitute capital for labor until the RTS between these factors is equal to one.

If retailers are using information technology efficiently, the RTS of productive factors, as measured in dollar units, should be equal to one. Thus, the market for information technology is efficient if the RTS between information technology and capital and also between information technology and labor are equal to one. The following hypotheses examine these propositions:

H4a: Retailers operate on the production function where the Rate of Technical Substitution (RTS) between information technology and capital, as measured in dollar values, is equal to one; and

H4b: Retailers operate on the production function where the Rate of Technical Substitution (RTS) between information technology and labor, as measured in dollar values, is equal to one.
Data Collection

Data for this study were collected from retailers located in within the Dallas-Fort Worth CMSA, as defined by the U.S. Bureau of Census. Rural, suburban, and metropolitan areas are all contained within this sample frame.

The sample was drawn using self-administered surveys. These surveys were delivered as part of a class project by undergraduate students who earned class credit. The students were not be involved in the data collection beyond the survey delivery process. This delivery process was used to increase the potential response rate. Mail surveys suffer from poor response rates that usually range less than 20 percent (Fox et al. 1988). Personal delivery resulted in a much higher effective response rate during a pilot study than would be expected from a mail survey.

Retailers are divided into categories based on their major two-digit SIC code. The major SIC categories are: 52 - building materials and nurseries; 53 - department and variety stores; 54 - food stores; 55 - auto dealers and parts; 56 - apparel stores; 57 - furniture and home furnishings; 58 - eating and drinking places; and 59 - miscellaneous stores. These SIC categories offer an exhaustive cross section of product retailers.

A non-probability sample of 871 stores was surveyed from the sample frame. Of these, 521 surveys (59.8 percent) included enough information to compute the output measure. A description of the usable sample is shown in Table 4.1 in Chapter IV.
The sample allows for at least 30 observations per SIC retail category (52 - 59). This is in line with the minimum recommended by Hair et al. (1994), who suggests a minimum of 10 observations for each independent (predictor) variable when using regression analysis.

**Testing For Biases**

Non-probability samples suffer from several potential problems (Assael and Keon 1982). The greatest threat is non-representativeness of the items within the sample. This can bias the results of the analysis toward the items that are over-represented and against those items that are under-represented. This potential problem needs to be examined.

**Sampling Bias**

Sampling bias is examined by testing for differences in the respondent characteristics from the sample frame characteristics. Specifically, the sample was compared to data from the 1992 U.S. Census of Retail Trade to ensure representativeness. T-tests compared the Census data and sample using gross sales, total payroll, and the number of employees for each SIC category and the aggregate sample.
Non-response Bias

As was expected, some retailers declined to answer some questions due to the proprietary nature of the data. This could potentially result in a non-response bias. Two steps were taken to reduce and measure these effects. First, in order to minimize the number of non-responses, a confidentiality form was included as part of the cover sheet on the survey. Second, non-response bias was examined by comparing the sample of those that responded (n=521) and those who refused to complete the survey (n=350). The results of these tests are shown in Table 4.3 in Chapter IV.

Measures

The survey instrument consists of six major parts, as shown in the Appendix. The first page is a letter of introduction and statement of confidentiality. The letter of introduction informs the retailer of the purpose of the research. The statement of confidentiality is to assure the retailer that the information will be used for only research purposes. This is added to the survey to increase the response rate.

The second major part of the survey instrument asked the retailer to identify some basic characteristics about the firm. Included in this section are the major SIC code; county of operation; affiliation of the retailer (independent, chain, or franchise); ownership of the firm (proprietorship, partnership, or corporation); management of the firm (owner managed or non-owner managed); and location of the store.
The next three sections of the survey request information relating to the major measures used in the research. The labor section, titled "EMPLOYEES," requests information on the number of employees and the total payroll of the retailer. The capital section, titled "Store Size and Location" requests location characteristics, the size of the store in square feet, and the amount that the retailer pays in rent or lease. The section, titled "INFORMATION TECHNOLOGY," requests measures of the amount of information technology employed by the firm and the amount of money invested in this technology.

The next section asks the retailers what type of productivity measures they use to evaluate their employees. This section is included as an addendum to the major thrust of the research, as a descriptive measure of interest.

The last section of the survey, titled "OPERATION MEASURES," measures the output of the retailer. As discussed previously, output was measured as value added and gross sales. Both of these measures were obtained from the information in this section.

Output. As discussed previously, there are no universally accepted measures of retail output. However, it is generally accepted that the measure which most closely resembles the output of a retailer is value added (Doutt 1984; Good 1984; Lusch and Moon 1984; Ingene 1984; Ratchford and Brown 1985; Lusch 1980). This was calculated as the gross margin of the retailer by either multiplying gross sales by gross margin or by subtracting Cost of Goods Sold (COGS) from gross sales. The survey gave retailers an option of stating either gross margin percentage or cost of goods sold.
Inputs. Three factor inputs are examined in this research: capital, labor, and information technology. Each was measured using three different methods: absolute physical units; absolute dollar units; and physical units weighted by dollar value. As discussed in Chapter II, both capital and labor have traditionally been measured using absolute physical numbers or dollar values. This research provides multiple measures to ensure the robustness of the results.

Labor Measures. Retail labor has traditionally been measured as the number of Full-Time-Equivalent employees (Lusch and Moon 1984; Takeuchi and Bucklin 1977). The number of FTE employees is used in this research to represent the physical amount of labor used. Other authors, such as Lusch (1980), use dollar value instead of physical measures of labor. The measure of dollar labor units is represented by payroll (total of wages and salaries) for the same year in which the output is measured. This is in line with other authors' operationalization of this measure (Lusch 1980). All previous measures of physical labor treated all employees as equal in value to the firm. While this assumption is common, and it appears to be useful, this research attempts to provide a more accurate measure of physical labor. The third measure of labor consists of a weighted composite of physical labor units. Each FTE employee was measured by weighting each type of labor by the appropriate market value. The employee types used for weighting are based on supervisory and non-supervisory employees, as commonly used by the U.S. Bureau of Labor Statistics.

Capital Measures. Retail capital is traditionally interpreted as the amount of space, as measured by square footage, in a retail store (Thurik and Kooiman 1986;
Arndt and Olsen 1975; Good 1984; Tilley and Hicks 1970; Ingene 1982; Ingene and Lusch 1981). This interpretation is also adopted here to represent the physical input of capital. Another unit of capital is the cost of retail space (Lusch 1980; Ingene and Lusch 1979). In this study, rent represents the absolute dollar value of retail space. A third measure of capital consists of a weighted composite of space. Square footage was weighted by type of location. A market value for each was used in the weighting process, as discussed below.

**Information Technology Measures.** Information technology has previously been measured only through either aggregate dollar value for the economy as a whole or through the use of semantic differential scales (Weber 1990). In this research, information technology is measured using the same three parameters as other input measures. This allows for separation, inclusion, and direct comparison of information technology with other factor input measures.

As discussed in Chapter II, an examination of the literature and a prior pilot study revealed 19 specific types of information technology that have the potential to increase retail productivity: Universal Product Code (UPC) scanners, electronic cash registers, electronic credit card approval systems, electronic check approval devices, facsimile (fax) machines, barcode printers, computer terminals, laptop computers, desktop/personal computers (PCs), computer printers, specialized software, electronic mail (E-mail), Point-Of-Sale (POS) systems, Management Information Systems (MIS), computerized accounting and bookkeeping systems, Electronic Data Interchange (EDI) systems, Quick Response (QR) systems, computerized inventory tracking systems, and
computerized buying/ordering systems. These measures are described further in Table 3.4.

The physical number of each type represents a measure of the physical amount of information technology in the retail firm. The systems are measured using a dummy variable format. An estimate from the respondents of the amount of money spent on information technology is used to represent the dollar value of this information technology. Lastly, a weighted composite of all information technology according to relative market value is used as a single aggregated measure of information technology. The weighting system is based on market values of each type of technology, as discussed below.

Weighting System

The weights for the input variables were derived using the following formula:

\[
\text{Weight}_i = \frac{\text{Market Value}_i}{\sum (\text{Market Value}_i/i)}
\]

Composites of each variable were estimated by multiplying the weights by the number of units of each type of input and summing the results for each of the three inputs. These values represent a composite value of the amount of labor, capital, and information technology for estimation of a production function.
Functional Form

It is necessary to adjust the traditional translog production function due to the physical measures of information technology. The traditional translog requires the natural log of each input for use in linear regression. However, the measures of information technology often have values of zero due to the dummy variable coding scheme, making the transformation impossible. The functional form is adjusted as:

\[
\text{Output (Q)} = \beta_0 (K^{\beta_1}) (L^{\beta_1}) e^{\beta_2 (L) + \beta_2 (K) + \beta_2 (IT)}
\]

This function lacks the traditional estimation of the elasticity of the input.

The monetary and weighted variables suffer from no such constraints. Thus a traditional translog production function is used.

\[
\text{Output (Q)} = \beta_0 (K^{\beta_1}) (L^{\beta_1}) (IT^{\beta_1}) e^{\beta_2 (L) + \beta_2 (K) + \beta_2 (IT)}
\]

Further, a partial F test was conducted on the translog for the subset \(e^{\beta_2 (L) + \beta_2 (K) + \beta_2 (IT)}\), as shown in Chapter IV, which indicates that the function can be reduced to a Cobb-Douglas form.

\[
\text{Output (Q)} = \beta_0 (K^{\beta_1}) (L^{\beta_1}) (IT^{\beta_1})
\]

In order to use multiple regression analysis, this functional form was transformed to a linear function, as shown in Equation 3.12.

\[
\ln(Q) = \beta_0 + \beta_1 (\ln(K)) + \beta_2 (\ln(L)) + \beta_3 (\ln(IT))
\]

This transformation is achieved by taking the natural logarithmic (\(\ln\)) of both sides of the equation.
Production functions were estimated for each type of independent variable: physical, monetary, and weighted. A total of three major production functions were estimated using regression analysis, as shown in Table 3.1.

### TABLE 3.1

**FUNCTIONAL FORM FOR PRODUCTION FUNCTION ESTIMATIONS**

<table>
<thead>
<tr>
<th>Functional Form</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Translog with Physical Input Measures</strong></td>
</tr>
<tr>
<td>(3.13) [ \ln(\text{VA}) = \beta_0 + \beta_1[\ln(\text{FTE})] + \beta_2[\ln(\text{SF})] + \beta_3[\ln(\text{IT}<em>0)] + \beta_4[\ln(\text{IT}<em>1)] + \beta_5[\ln(\text{IT}<em>2)] + \beta_6[\ln(\text{IT}<em>3)] + \beta_7[\ln(\text{IT}<em>4)] + \beta_8[\ln(\text{IT}<em>5)] + \beta_9[\ln(\text{IT}<em>6)] + \beta</em>{10}[\ln(\text{IT}<em>7)] + \beta</em>{11}[\ln(\text{IT}<em>8)] + \beta</em>{12}[\ln(\text{IT}<em>9)] + \beta</em>{13}[\ln(\text{IT}</em>{10})] + \beta</em>{14}[\ln(\text{IT}</em>{11})] + \beta</em>{15}[\ln(\text{IT}</em>{12})] + \beta</em>{16}[\ln(\text{IT}<em>{13})] + \beta</em>{17}[\ln(\text{IT}<em>{14})] + \beta</em>{18}[\ln(\text{IT}<em>{15})] + \beta</em>{19}[\ln(\text{IT}<em>{16})] + \beta</em>{20}[\ln(\text{IT}<em>{17})] + \beta</em>{21}[\ln(\text{IT}<em>{18})] + \beta</em>{22}[\ln(\text{IT}_{19})] ]</td>
</tr>
<tr>
<td><strong>Translog with Monetary Input Measures</strong></td>
</tr>
<tr>
<td>(3.14) [ \ln(\text{VA}) = \beta_0 + \beta_1[\ln(\text{PAY})] + \beta_2[\ln(\text{RENT})] + \beta_3[\ln(\text{IT COST})] + \beta_4[\ln(\text{FTE})] + \beta_5[\ln(\text{SF})] + \beta_6[\ln(\text{IT COST})] ]</td>
</tr>
<tr>
<td><strong>Translog with Weighted Input Measures</strong></td>
</tr>
<tr>
<td>(3.15) [ \ln(\text{VA}) = \beta_0 + \beta_1[\ln(L_w)] + \beta_2[\ln(K_w)] + \beta_3[\ln(\text{IT}_w)] + \beta_4[\ln(L_w)] + \beta_5[\ln(K_w)] + \beta_6[\ln(\text{IT}_w)] ]</td>
</tr>
<tr>
<td>Output Measures</td>
</tr>
<tr>
<td>-----------------</td>
</tr>
<tr>
<td>VA = Value added in dollars</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Physical Measures</th>
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</thead>
<tbody>
<tr>
<td>FTE = Number of full-time equivalent employees</td>
</tr>
<tr>
<td>SF = Total square footage of retail space</td>
</tr>
<tr>
<td>IT1 = Number of UPC scanners</td>
</tr>
<tr>
<td>IT2 = Number of electronic cash registers</td>
</tr>
<tr>
<td>IT3 = Number of electronic credit card approval devices</td>
</tr>
<tr>
<td>IT4 = Number of fax machines</td>
</tr>
<tr>
<td>IT5 = Number of barcode printers</td>
</tr>
<tr>
<td>IT6 = Number of computer terminals</td>
</tr>
<tr>
<td>IT7 = Number of laptop computers</td>
</tr>
<tr>
<td>IT8 = Number of personal or desktop computers</td>
</tr>
<tr>
<td>IT9 = Number of computer printers</td>
</tr>
<tr>
<td>IT10 = Number of custom software programs</td>
</tr>
<tr>
<td>IT11 = Number of electronic check approval devices</td>
</tr>
<tr>
<td>IT12 = Dummy variable for e-mail system</td>
</tr>
<tr>
<td>IT13 = Dummy variable for POS system</td>
</tr>
<tr>
<td>IT14 = Dummy variable for MIS system</td>
</tr>
<tr>
<td>IT15 = Dummy variable for accounting system</td>
</tr>
<tr>
<td>IT16 = Dummy variable for EDI system</td>
</tr>
<tr>
<td>IT17 = Dummy variable for QR</td>
</tr>
<tr>
<td>IT18 = Dummy variable for inventory tracking</td>
</tr>
<tr>
<td>IT19 = Dummy variable for buying/ordering</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dollar Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAY = Total payroll</td>
</tr>
<tr>
<td>RENT = Total rent costs</td>
</tr>
<tr>
<td>IT COST = Investment in information technology</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Weighted Composite Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>L_w = Weighted composite of labor</td>
</tr>
<tr>
<td>K_w = Weighted composite of capital</td>
</tr>
<tr>
<td>I_T_w = Weighted composite of information technology</td>
</tr>
</tbody>
</table>

\textsuperscript{1} - For all dummy variables, 1 represents the existence of an information technology and 0 represents the absence of a given information technology.
Analytic Method

Two major analytic methods were used to manipulate the data: Ordinary Least Squares (OLS) regression for the aggregate sample and Two-Stage Least Squares (2SLS) regression for the analysis by SIC categories. Initial analysis of the sample indicated that the production functions could not be estimated using casewise deletion at the SIC code level due to data insufficiencies on one or more variables. Therefore, each of the six equations in Table 3.4 was estimated using 2SLS regression.

2SLS regression

In order to adjust for this a Two Stage Least Squares (2SLS) method was applied. This method is traditionally used to avoid assumption violations in the case of a lagged endogenous variable being used as a exogenous variable (Gujarati 1988; Greene 1990). It has been shown to be efficient and to provide unbiased estimates in both the first and second stage if the first stage estimates have an R-Squared above 0.80 (Gujarati 1988, p.606).

This method estimates the independent variables using the first stage and then uses the predicted estimates of the independent variables as an input into the second stage. Because the main analysis is using estimated instead of actual data, the standard error of the estimates must be recalibrated by using the adjustment factor as shown by Gujarati (1988, Appendix 19A.2).
First Stage Equations. As indicated above, it is necessary to provide relatively good estimations to the second stage of the analysis. This was done by creating regression equations to estimate values for PAY, RENT, and IT COST. Payroll was estimated as a function of the type of business by SIC code, the location of the business by county, the number of managers employed, and the number of non-managerial employees. Rent was estimated as a function of the type of business by SIC code, the location of the business by location type and county, and the ownership type of the store. Investment of information technology was estimated using the type of business by SIC code and the type of technology, IT1 through IT19.

Second Stage Estimations. The predicted values for PAY, RENT and IT COST from the first stage equations were utilized in the translog functions (equations 3.14 and 3.17). Also, the standard errors were adjusted as indicated by Gujarati (1988, Appendix 19A.2). The results of both the first and second stages are shown in Chapter IV.

Testing of Hypotheses

The first hypothesis, that information technology has a positive and statistically significant impact on retail productivity, was tested using partial F-tests and t-tests. A partial F test was conducted on equation 3.13 for the variables IT1 through IT19 (see Table 3.1). A t- test was conducted on $\beta_a$ for estimation of equations 3.14 and 3.15.
The second hypothesis explores the homogeneity of the production function. It suggests that firms will operate at constant returns to scale. This was tested by examining the passus coefficient (Arndt and Olsen 1975) for equations 3.14 and 3.15. The passus coefficient, signified by $\Omega$, in each equation is equal to:

\[
(3.16) \quad \Omega = \beta_i + \beta_k + \beta_t
\]

This was tested using an expansion of the test discussed by Lusch (1980). The formal value of the $t$ statistic for $\Omega = 1$ was calculated as:

\[
(3.17) \quad t = (\beta_i + \beta_k + \beta_t - 1)/(\text{var} (\beta_i + \beta_k + \beta_t))^{0.5}
\]

for all estimations of equations 3.14 and 3.15.

The third hypothesis states that the marginal product of an input is equal to its marginal cost. Given the proposed functional form in equation 3.14, the marginal product for information technology is equal to:

\[
(3.18) \quad MP_{IT} = \frac{\partial VA}{\partial IT \text{ cost}} = \frac{(\beta_{IT})(VA)}{IT \text{ cost}}
\]

When output ($VA$) and information technology ($IT \text{ cost}$) are measured in dollars, the marginal product is interpreted as the number of dollars of output obtained by a dollar’s worth of input. Thus, the third hypothesis was tested by estimating equation 3.18 for each observation and using a $t$-test to statistically examine whether these values were equal to 1.0.

The fourth and final set of hypotheses relies on testing whether the Rate of Technical Substitution (RTS) is equal to 1.0 when both inputs and outputs are measured in dollar terms. Equation 3.14 was used to test these hypotheses, since they are the only forms in which both inputs and output are measured in dollars. The RTS of
technology for capital, given the production function in equation 3.14, was calculated as:

\[
\text{RTS of IT for } K = \frac{\text{MP}_K}{\text{MP}_K}
\]

\[
= \frac{(\partial VA/\partial \text{IT Cost})/(\partial VA/\partial \text{rent})}{(\partial VA/\partial \text{IT cost})/(\partial VA/\partial \text{rent})}
\]

\[
= \frac{[(\beta_{IT})(VA)/\text{IT cost}]/[(\beta_K)(VA)/\text{rent}]}{[(\beta_{IT})(\text{rent})]/[(\beta_K)(\text{IT cost})]}
\]

Similarly, the RTS of technology for labor is calculated as:

\[
\text{RTS of IT for } L = \frac{\text{MP}_L}{\text{MP}_L}
\]

\[
= \frac{(\partial VA/\partial \text{IT cost})/(\partial VA/\partial \text{pay})}{(\partial VA/\partial \text{IT cost})/(\partial VA/\partial \text{pay})}
\]

\[
= \frac{[(\beta_{IT})(VA)/\text{IT cost}]/[(\beta_L)(VA)/\text{pay}]}{[(\beta_{IT})(\text{pay})]/[(\beta_L)(\text{IT cost})]}
\]

The last set of hypotheses was tested by estimating a value for each observation using equations 3.19 and 3.20 and the \( \beta \) values from equation 3.14. A t-test then was used to statistically test whether the RTS estimates were equal to one.

**Chapter Summary**

This chapter develops specific research questions and hypotheses which are put into a theoretical framework for examination. The theory of the firm and the concept of a production function are employed to produce a methodology that allows for testing of the hypotheses. Lastly, a research instrument was developed based on the information needs of the research.
The fourth chapter of the research will present the statistical results from the data analysis. Following this, the fifth chapter will conclude the research effort with an interpretation and discussion of the results.
CHAPTER IV

RESEARCH RESULTS

This chapter presents the results of the analysis discussed in the previous chapter. First, the characteristics of the sample are presented, along with examination of the representativeness of the sample compared to the sample frame, and are tested for non-response bias. The results of the analysis using physical measures of inputs (FTE, floor space, and types of information technology) are then presented. This is followed by an examination of the statistical analysis used in the remainder of the chapter, including a comparison of the translog versus Cobb-Douglas functional forms and the first-stage of the Two Stage Least Squares (2SLS) regression analysis. The remainder of the chapter is divided into two parts: regression results using monetary measures of inputs (payroll, rent, and information technology investment) and results utilizing weighted measures of inputs.

Sample Characteristics

As discussed in Chapter III, data for this study were collected from retailers located in the Dallas-Fort Worth CMSA, as defined by the U.S. Bureau of Census. The sample was collected using self-administered surveys. A copy of the survey is
shown in the Appendix. The resultant sample was divided into categories based on two-digit SIC codes for product retailers. The major SIC categories used in this research are: 52 - building materials and nurseries; 53 - department and variety stores; 54 - food stores; 55 - auto dealers and parts; 56 - apparel stores; 57 - furniture and home furnishings; 58 - eating and drinking places; and 59 - miscellaneous stores. These SIC categories offer an exhaustive cross section of product retailers.

A non-probability sample of 871 stores was surveyed from the sample frame. Of these, 521 surveys (59.8 percent) included enough information to compute the output measure. The output measure, value added, was calculated from sales in conjunction with either gross margin percentage or Cost of Goods Sold (COGS). A description of the usable sample is shown in Table 4.1.

The sample allows for a minimum of 30 observations per SIC retail category (52 - 59), with general merchandise and variety stores (SIC 53) having the fewest (N=30) observations. Data from larger chain stores, which make up most of SIC 53, were more difficult to obtain due to relative scarcity of these stores and the common procedural guidelines of many larger chain stores against disclosing financial data of individual stores.
### TABLE 4.1

**SAMPLE CHARACTERISTICS**

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>TOTAL SAMPLE</th>
<th>52 BUILDING</th>
<th>53 GENERAL</th>
<th>54 FOOD</th>
<th>55 AUTO</th>
<th>56 APPAREL</th>
<th>57 FURNITURE</th>
<th>58 EATING</th>
<th>59 MISC</th>
</tr>
</thead>
<tbody>
<tr>
<td>N1</td>
<td>521</td>
<td>33</td>
<td>30</td>
<td>64</td>
<td>48</td>
<td>94</td>
<td>70</td>
<td>88</td>
<td>94</td>
</tr>
<tr>
<td>GROSS SALES</td>
<td>$3,833,645</td>
<td>$2,374,185</td>
<td>$13,623,149</td>
<td>$9,129,619</td>
<td>$8,480,144</td>
<td>$1,148,826</td>
<td>$1,153,820</td>
<td>$1,487,038</td>
<td>$2,120,504</td>
</tr>
<tr>
<td>(12,423,004)</td>
<td>(3,887,859)</td>
<td>(13,120,169)</td>
<td>(16,541,033)</td>
<td>(27,634,620)</td>
<td>(2,256,846)</td>
<td>(1,513,999)</td>
<td>(3,275,752)</td>
<td>(12,351,735)</td>
<td></td>
</tr>
<tr>
<td>VALUE ADDED</td>
<td>$1,125,172</td>
<td>$763,849</td>
<td>$4,735,717</td>
<td>$2,152,027</td>
<td>$1,175,156</td>
<td>$467,342</td>
<td>$501,086</td>
<td>$847,383</td>
<td>$757,688</td>
</tr>
<tr>
<td>(3,200,639)</td>
<td>(1,174,385)</td>
<td>(6,944,572)</td>
<td>(3,974,030)</td>
<td>(3,123,826)</td>
<td>(1,192,440)</td>
<td>(720,523)</td>
<td>(1,704,511)</td>
<td>(3,961,331)</td>
<td></td>
</tr>
<tr>
<td>YEARLY PAYROLL</td>
<td>$325,614</td>
<td>$195,839</td>
<td>$1,858,128</td>
<td>$375,507</td>
<td>$442,067</td>
<td>$81,756</td>
<td>$144,518</td>
<td>$257,092</td>
<td>$144,097</td>
</tr>
<tr>
<td>(920,131)</td>
<td>(202,159)</td>
<td>(3,351,733)</td>
<td>(706,863)</td>
<td>(742,224)</td>
<td>(84,445)</td>
<td>(177,294)</td>
<td>(324,140)</td>
<td>(310,195)</td>
<td></td>
</tr>
<tr>
<td>EMPLOYEES (FTE)</td>
<td>26.56</td>
<td>15.95</td>
<td>86.18</td>
<td>51.35</td>
<td>28.33</td>
<td>11.00</td>
<td>8.13</td>
<td>38.72</td>
<td>11.22</td>
</tr>
<tr>
<td>(51.18)</td>
<td>(19.37)</td>
<td>(88.87)</td>
<td>(62.40)</td>
<td>(59.52)</td>
<td>(17.05)</td>
<td>(7.22)</td>
<td>(68.56)</td>
<td>(19.70)</td>
<td></td>
</tr>
<tr>
<td>YEARLY RENT</td>
<td>$58,876</td>
<td>$41,663</td>
<td>$204,137</td>
<td>$106,910</td>
<td>$74,834</td>
<td>$55,377</td>
<td>$41,537</td>
<td>$40,900</td>
<td>$34,683</td>
</tr>
<tr>
<td>(116,069)</td>
<td>(47,043)</td>
<td>(322,870)</td>
<td>(142,542)</td>
<td>(128,226)</td>
<td>(166,955)</td>
<td>(43,257)</td>
<td>(31,847)</td>
<td>(41,909)</td>
<td></td>
</tr>
<tr>
<td>SQUARE FOOTAGE</td>
<td>13,647</td>
<td>15,804</td>
<td>65,884</td>
<td>22,146</td>
<td>22,765</td>
<td>5,529</td>
<td>7,787</td>
<td>7,030</td>
<td>4,452</td>
</tr>
<tr>
<td>(31,837)</td>
<td>(16,466)</td>
<td>(82,889)</td>
<td>(23,160)</td>
<td>(54,103)</td>
<td>(12,672)</td>
<td>(9,566)</td>
<td>(11,519)</td>
<td>(6,518)</td>
<td></td>
</tr>
<tr>
<td>IT INVESTMENT</td>
<td>$58,936</td>
<td>$60,812</td>
<td>$438,100</td>
<td>$88,517</td>
<td>$96,496</td>
<td>$11,726</td>
<td>$22,767</td>
<td>$65,592</td>
<td>$15,374</td>
</tr>
<tr>
<td>(227,728)</td>
<td>(152,019)</td>
<td>(919,754)</td>
<td>(179,469)</td>
<td>(184,611)</td>
<td>(14,096)</td>
<td>(36,278)</td>
<td>(270,236)</td>
<td>(21,569)</td>
<td></td>
</tr>
</tbody>
</table>

1 - Number of responses with both SALES and MARGIN complete

Note: Standard deviations are in parentheses
The largest value on every variable occurred in SIC 53 (general merchandise and variety stores), with food stores ranking second in size. The smallest stores were apparel, furniture or miscellaneous stores, depending on the measure used. The highest variance relative to the mean was found in food and auto stores. This is not surprising given the breadth of store sizes found in these categories. Food stores range in size from the largest supermarkets to the corner grocer. Automotive stores include both automobile dealers and small parts stores. The high relative variance in these stores is likely to result in high standard errors in the regression analysis, possibly resulting in insignificant coefficients (Gujarati 1988).

Testing For Biases

Non-probability samples suffer from several potential problems. Two potential biases can occur in this type of sample. First, sampling bias, which is unique to non-probability samples, is the threat of choosing a sample from the sample frame that is not representative of the items in the population. The second threat, non-response bias, is not unique to non-probability samples. Non-response bias occurs when a group of respondents with common characteristics refuse to respond to the survey at a different rate than other respondents. The results of examination for these potential biases are discussed below.
Sampling Bias

Sampling bias was examined by testing for differences in the central tendency between the respondent characteristics and those of the sample frame. Specifically, the sample was compared to data from the 1992 U.S. Census of Retail Trade in relation to the Dallas-Fort Worth CMSA. The results of the t-tests comparing the census data and sample observations for each SIC category are shown in Table 4.2.

### Table 4.2

<table>
<thead>
<tr>
<th>SIC Category</th>
<th>t-value for difference in GROSS SALES</th>
<th>t-value for difference in PAYROLL</th>
<th>t-value for difference in EMPLOYEES</th>
</tr>
</thead>
<tbody>
<tr>
<td>52 - Building Materials</td>
<td>0.0946 (p = .3510)</td>
<td>-0.142 (p = .8879)</td>
<td>1.388 (p = .1744)</td>
</tr>
<tr>
<td>53 - General Merchandise</td>
<td>1.642 (p = .1110)</td>
<td>-1.000 (p = .3253)</td>
<td>0.653 (p = .5187)</td>
</tr>
<tr>
<td>54 - Food</td>
<td>3.406 (p = .0011)</td>
<td>0.640 (p = .5245)</td>
<td>4.223* (p &lt; .0001)</td>
</tr>
<tr>
<td>55 - Automotive</td>
<td>0.788 (p = .4346)</td>
<td>0.270 (p = .7883)</td>
<td>1.509 (p = .1379)</td>
</tr>
<tr>
<td>56 - Apparel</td>
<td>1.722 (p = .0884)</td>
<td>-1.559 (p = .1224)</td>
<td>1.518 (p = .1324)</td>
</tr>
<tr>
<td>57 - Furniture</td>
<td>0.190 (p = .8499)</td>
<td>-2.684 (p = .0091)</td>
<td>0.486 (p = .6285)</td>
</tr>
<tr>
<td>58 - Eating/Drinking</td>
<td>2.592 (p = .0112)</td>
<td>-5.064* (p &lt; .0001)</td>
<td>2.781 (p = .0066)</td>
</tr>
<tr>
<td>59 - Miscellaneous</td>
<td>1.104 (p = .2724)</td>
<td>-4.542* (p = .0002)</td>
<td>2.305 (p = .0234)</td>
</tr>
</tbody>
</table>

* - significant at .05 level after Bonferroni adjustment for alpha inflation
Of the eight SIC categories shown in Table 4.2, there are a total of eight significant differences at the .05 significance level on three variables: average sales, payroll, and number of employees. After using a Bonferroni adjustment for alpha inflation, only three of 24 differences remain significant at the .05 level: SALES for SIC 54 and PAYROLL for SIC 58 and 59. While there are some differences, these are attributed to the difference in economic climates over the differing time periods (1992-1995). Overall, it can be concluded that the sample is reasonably representative of the sample frame.

Non-response Bias

As expected, some retailers declined to answer some questions due to the proprietary nature of the data. Non-response bias was examined by comparing the sample of participants that responded ($N = 521$) to those who declined to complete the survey ($N = 350$). Complete versus incomplete surveys were categorized based on the ability to compute the dependent measure, value added. These samples are compared on 22 variables that encompass measures for both the dependent and independent variables. Measures that displayed interval or ratio measurement characteristics were used in this analysis. The results of the t-tests for sample differences are shown in Table 4.3.
<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>t-value for sample difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Years in Business</td>
<td>1.17 (p = .224)</td>
</tr>
<tr>
<td>Gross Sales</td>
<td>-0.99 (p = .333)</td>
</tr>
<tr>
<td>Number of Employees</td>
<td>-0.87 (p = .385)</td>
</tr>
<tr>
<td>Number of managers</td>
<td>-1.32 (p = .186)</td>
</tr>
<tr>
<td>Number of Full-time Salespeople</td>
<td>-1.12 (p = .262)</td>
</tr>
<tr>
<td>Number of Part-time Salespeople</td>
<td>-0.52 (p = .605)</td>
</tr>
<tr>
<td>Hours worked by part-time salespeople</td>
<td>1.69 (p = .091)</td>
</tr>
<tr>
<td>Monthly Payroll</td>
<td>-0.81 (p = .419)</td>
</tr>
<tr>
<td>Monthly Rent</td>
<td>-0.05 (p = .960)</td>
</tr>
<tr>
<td>Total Square Feet</td>
<td>2.29 (p = .022)</td>
</tr>
<tr>
<td>UPC Scanners</td>
<td>-1.67 (p = .097)</td>
</tr>
<tr>
<td>Number of Cash Registers</td>
<td>-1.63 (p = .104)</td>
</tr>
<tr>
<td>Credit Card Approval Devices</td>
<td>-1.77 (p = .078)</td>
</tr>
<tr>
<td>Faesimile Machines</td>
<td>-0.26 (p = .797)</td>
</tr>
<tr>
<td>Barcode Printers</td>
<td>0.76 (p = .447)</td>
</tr>
<tr>
<td>Computer Terminals</td>
<td>0.66 (p = .509)</td>
</tr>
<tr>
<td>Laptop Computers</td>
<td>-0.90 (p = .381)</td>
</tr>
<tr>
<td>Personal Computers</td>
<td>-1.25 (p = .214)</td>
</tr>
<tr>
<td>Computer Printers</td>
<td>-0.85 (p = .397)</td>
</tr>
<tr>
<td>Specialized Software</td>
<td>-0.60 (p = .551)</td>
</tr>
<tr>
<td>Check Approval Devices</td>
<td>-1.59 (p = .116)</td>
</tr>
<tr>
<td>Investment in Information Technology</td>
<td>-0.99 (p = .326)</td>
</tr>
</tbody>
</table>
Of the 22 t-tests, only one variable is significant at the .05 level. After correcting for alpha inflation using a Bonferroni adjustment, there are no differences between the samples. Overall, these results indicate very little, if any, non-response bias.

The analysis of the sample characteristics for both sampling and non-response bias indicates that the sample is representative of the sample frame. This is paramount for external validity to exist. It is concluded that the sample is sufficiently representative to allow the generalization of the results to the sample frame.

**Results of the Modified Translog Using Physical Input Measures**

As indicated in Chapter II and III, physical measures of input factors are recommended for productivity analysis (Lusch and Ingene 1979). As is common in other research, square footage of floor space (Tilley and Hicks 1970; Arndt and Olsen 1975; Lusch and Ingene 1979; Ingene 1982, 1984, 1985; Lusch and Moon 1984; Thurik and Kooiman 1986) and the number of employees (Hall, Knapp and Winsten 1961; George 1966; Schwartzman 1971; Arndt and Olsen 1975; Bucklin 1978; Lusch and Ingene 1979; Ingene 1982, 1984; Lusch and Moon 1984) were used to measure capital and labor, respectively. No previous analysis has examined information technology as a productive input factor. The measures of information technology were developed using prior literature, as discussed in Chapter II, and a pilot study.
As recommended by Ratchford and Stoops (1988), a translog function was utilized. However, it is necessary to adjust the traditional translog from,

\[(4.1) \quad \text{Output } (Q) = \beta_0 (K^{\beta_1}) (L^{\beta_1}) (IT^{\beta_1}) e^{\beta_2 (L) + \beta_2 (K) + \beta (IT)} \]

to

\[(4.2) \quad \text{Output } (Q) = \beta_0 (K^{\beta_1}) (L^{\beta_1}) e^{\beta_2 (L) + \beta_2 (K) + \beta (IT)} .\]

This transformation is necessary due to non-positive (i.e. zero value) measures of information technology in certain categories, making it mathematically impossible to take the natural log (ln) of information technology measures. The results of this analysis are shown in Table 4.4.

The results in Table 4.4 show that the estimated coefficient of each input is significant on at least one variable. The coefficients of both the elasticity of labor and capital are significant. A partial F test indicates that the coefficients of information technology in the second set of variables \((e^{\beta_2 (L) + \beta_2 (K) + \beta (IT)})\) are significant as a group (IT1 to IT19). These results lend support for the first hypothesis — that information technology is a productive factor in retailing. The coefficients of this set of variables are not interpreted as estimates of elasticity, but rather as changes in the percent of output obtained, based on changes in units of inputs.
TABLE 4.4

OLS WITH PHYSICAL INPUT MEASURES FOR AGGREGATE SAMPLE

\[
\text{Output (Q)} = \beta_0 \left( K^{\beta_k1} \right) \left( L^{\beta_l1} \right) e^{\left[ \beta_{l2} (L) + \beta_{k2} (K) + \beta_{TT} \right]}
\]

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Coefficient Estimate</th>
<th>F</th>
<th>Significance Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information Technology ((e^{\beta_{TT}}))</td>
<td>n/a (19)-variables</td>
<td>Partial F = 1.91235</td>
<td>(p = .0116)</td>
</tr>
<tr>
<td>Labor ((e^{\beta_{l2}(L)})</td>
<td>(\beta_{l2} = -0.024549)</td>
<td>0.299</td>
<td>(p = .5847)</td>
</tr>
<tr>
<td>Capital ((e^{\beta_{k2}(K)})</td>
<td>(\beta_{k2} = 0.018370)</td>
<td>0.167</td>
<td>(p = .6826)</td>
</tr>
<tr>
<td>Labor Elasticity ((L^{\beta_{l1}}))</td>
<td>(\beta_{l1} = 0.390170)</td>
<td>89.066</td>
<td>(p &lt; .0001)</td>
</tr>
<tr>
<td>Capital Elasticity ((K^{\beta_{k1}}))</td>
<td>(\beta_{k1} = 0.198920)</td>
<td>20.435</td>
<td>(p &lt; .0001)</td>
</tr>
</tbody>
</table>
Analytical Method

Initial analysis of the sample indicated that the production functions could not be estimated using casewise deletion at the SIC code level due to data insufficiencies on one or more variables. This problem was resolved through the use of 2SLS regression.

2SLS regression

Two Stage Least Squares (2SLS) regression (Gujarati 1988; Greene 1990) has been shown to be efficient and to provide unbiased estimates in both the first and second stage if the first stage estimates have an R-squared above 0.80 (Gujarati 1988, p. 606). This method estimates a linear equation to predict the independent variables of the production function during the first stage and then uses the predicted estimates as independent variables in the second stage. Because the main analysis is using estimated instead of actual data, the standard error of the estimates must be calibrated by using the adjustment factor as shown by Gujarati (1988, Appendix 19A.2). Ratchford and Stoops (1988, p. 251) experimented with this method of analyzing productivity, but indicated that the results from OLS regression were more plausible in their analysis.
First Stage Regression Results

As indicated above, it is necessary to provide relatively good estimations to the second stage of the analysis. Three first-stage regression analyses were performed to estimate values for the natural log of PAY, RENT, and IT COST. Payroll was estimated as a function of the type of business by SIC code, the location of the business by county, the number of managers employed, and the number of non-managerial employees. Rent was estimated as a function of the type of business by SIC code, the location of the business by location type and county, and the ownership type of the store. Investment of information technology was estimated using the type of business by SIC code and the type of technology, IT1 through IT19. The results of these regression estimations are shown in Table 4.6.

The results show high R-squared values, well above the 0.80 recommended by Gujarati (1988, p.606). These equations explain over 98 percent of the variance in each dependent variable. It is concluded that the predictions of ln(PAYROLL), ln(RENT), and ln(IT INVEST) developed from the estimated equations are unbiased and accurate.
## TABLE 4.6

**FIRST STAGE OF 2SLS RESULTS FOR RENT**

<table>
<thead>
<tr>
<th>DEPENDENT VARIABLE</th>
<th>INDEPENDENT VARIABLES</th>
<th>R-SQUARED</th>
<th>R-SQUARED ADJUSTED</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ln(RENT)</td>
<td>SIC</td>
<td>.99611</td>
<td>.99572</td>
<td>2546.5394</td>
</tr>
<tr>
<td></td>
<td>County X Location</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ownership</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Floor Space (ft²)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ln(PAYROLL)</td>
<td>SIC</td>
<td>.99783</td>
<td>.99774</td>
<td>12227.72</td>
</tr>
<tr>
<td></td>
<td>County X Number Managers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>County X Number Non-Managers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ln(IT INVESTMENT)</td>
<td>SIC</td>
<td>.98155</td>
<td>.97984</td>
<td>575.3674</td>
</tr>
<tr>
<td></td>
<td>IT1 through IT19</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**WHERE:**

- **SIC** = Dummy code for each SIC (52 through 59)
- **County** = Dummy code for each county
  - (Dallas, Denton, Tarrant, Other)
- **Location** = Dummy code for each location type:
  - (Regional Mall, Community Mall, Neighborhood Mall, Strip Mall, Factory Outlet, Downtown, Commercial District, Stand Alone)
- **Ownership** = Dummy code for ownership type
  - 1 = owner managed
  - 0 = professional management
The adjustment factor \((\sigma^2 / \sigma^2)\) for the standard errors of the estimates was calibrated by using the method discussed by Gujarati (1988, Appendix 19A.2). The resultant adjustment is equal to 0.878357703. As indicated by Gujarati (1988), this factor is relatively close to 1.0 due to the high predictive ability of the first stage equations. He further indicates that under such conditions "the estimated standard errors in the second-stage regression may be taken as true estimates" (p. 621).

Further analysis indicates that the significance of the results does not change whether or not the adjustment is used. The results in the second-stage estimates include the adjustment because it is an unbiased estimate of the standard errors.

**Translog Versus Cobb-Douglas Functions**

Authors have tended to use different functional forms to estimate production functions. The most common is the Cobb-Douglas function (Arndt and Olsen 1975; Ingene and Lusch 1979; Lusch 1980; Ingene 1984; Doutt 1984; Thurik and Kooiman 1986). In a relatively recent article, Ratchford and Stoops (1988) indicate that a translog function performs better in an Ehrlich-Fisher time-series model. The difference between a Cobb-Douglas and translog function is tested by using a partial F statistic on the \(e^{[\beta_1(L) + \beta_2(K) + \beta_3(T^2)]}\) portion of the translog equation. The results of this analysis are shown in Table 4.5.
TABLE 4.5

TRANSLOG VERSUS COBB-DOUGLAS PRODUCTION FUNCTIONS

<table>
<thead>
<tr>
<th>SAMPLE</th>
<th>Partial F-ratio of ( e^{\beta_2(L) + \beta_2(K) + \beta_2(T_i)} ) for Monetary Vars</th>
<th>Partial F-ratio of ( e^{\beta_2(L) + \beta_2(K) + \beta_2(T_i)} ) for Weighted Vars</th>
</tr>
</thead>
<tbody>
<tr>
<td>All data</td>
<td>( F = 1.06606 ) ( (p = .3631) )</td>
<td>( F = 0.08700 ) ( (p = .9672) )</td>
</tr>
<tr>
<td>SIC 52 Building</td>
<td>( F = 0.33669 ) ( (p = .7989) )</td>
<td>( F = 2.44979 ) ( (p = .0861) )</td>
</tr>
<tr>
<td>SIC 53 General Merch</td>
<td>( F = 0.74112 ) ( (p = .5384) )</td>
<td>( F = 2.52551 ) ( (p = .0829) )</td>
</tr>
<tr>
<td>SIC 54 Food Stores</td>
<td>( F = 0.25253 ) ( (p = .8592) )</td>
<td>( F = 0.02620 ) ( (p = .9942) )</td>
</tr>
<tr>
<td>SIC 55 Automotive</td>
<td>( F = 0.84165 ) ( (p = .4794) )</td>
<td>( F = 1.56736 ) ( (p = .2119) )</td>
</tr>
<tr>
<td>SIC 56 Apparel</td>
<td>( F = 1.23441 ) ( (p = .3024) )</td>
<td>( F = 0.40566 ) ( (p = .7493) )</td>
</tr>
<tr>
<td>SIC 57 Furniture</td>
<td>( F = 0.31039 ) ( (p = .8178) )</td>
<td>( F = 0.15859 ) ( (p = .9237) )</td>
</tr>
<tr>
<td>SIC 58 Eating/Drinking</td>
<td>( F = 1.78978 ) ( (p = .1558) )</td>
<td>( F = 0.60272 ) ( (p = .6151) )</td>
</tr>
<tr>
<td>SIC 59 Miscellaneous</td>
<td>( F = 0.92762 ) ( (p = .4313) )</td>
<td>( F = 1.71770 ) ( (p = .1695) )</td>
</tr>
</tbody>
</table>

The results show no significant differences between the use of a translog and Cobb-Douglas function for either monetary or weighted variables at the 0.05 significance level. It is concluded that the Cobb-Douglas function performs at least as well as the translog. The Cobb-Douglas is used to analyze the remaining results due to
its desirable characteristics of parsimony by conserving degrees of freedom and simplicity in calculating the returns to scale test (Lusch 1980).

Monetary Input Measures

This section examines the results of the production function estimates using monetary measures of inputs. The first analysis uses OLS regression on monetary variables (Payroll, Rent, and IT investment) from the survey for the aggregate sample. The second analysis uses predicted monetary input variables from the first-stage of the 2SLS regressions as inputs to the second-stage, which is the estimation of the production function by SIC. It should also be noted that the term elasticity in this section refers to dollar elasticity and not the traditional unit elasticity which is the common usage. The interpretation of dollar elasticity is the ratio of the percent changes in output dollars achieved by a percent change in the dollars of an input holding all other inputs constant.

Regression Results for Aggregate Sample Using OLS

A Cobb-Douglas production function was estimated using OLS regression for the full sample. The results of this analysis are provided in Table 4.7. The comparison between the Cobb-Douglas and translog functions are provided in the second half of the table.
TABLE 4.7

OLS RESULTS FOR AGGREGATE SAMPLE WITH MONETARY MEASURES

**COBB-DOUGLAS** - Output \( (Q) = \beta_0 (K^{\beta_k})(L^{\beta_l})(IT^{\beta_{it}}) \)

<table>
<thead>
<tr>
<th>IT Ln (IT INVEST)</th>
<th>Capital Ln (Rent)</th>
<th>Labor Ln (Payroll)</th>
<th>R Squared (R Squared Adjusted)</th>
<th>Passus Coefficient (t-ratio for Passus = 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \beta_{it} = 0.278737 ) ( (F = 11.290, p = .0001) )</td>
<td>( \beta_k = 0.270228 ) ( (F = 15.519, p = .0001) )</td>
<td>( \beta_l = 0.446123 ) ( (F = 48.951, p &lt; .0001) )</td>
<td>.60816</td>
<td>.995088</td>
</tr>
</tbody>
</table>

**TRANSLOG** - Output \( (Q) = \beta_0 (K^{\beta_k})(L^{\beta_l})(IT^{\beta_{it}}) e^{[\beta_2 (L) + \beta_r (K) + \beta_1 (IT)]} \)

<table>
<thead>
<tr>
<th>Information Technology</th>
<th>Capital</th>
<th>Labor</th>
<th>R Squared (R Squared Change from Cobb-Douglas)</th>
<th>Partial F test of ( e^{[\beta_2 (L) + \beta_r (K) + \beta_1 (IT)]} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \beta_{it} = 0.304996 ) ( (F = 19.897, p &lt; .0001) )</td>
<td>( \beta_k = 0.222532 ) ( (F = 10.107, p = .0017) )</td>
<td>( \beta_l = 0.429332 ) ( (F = 43.840, p &lt; .0001) )</td>
<td>.62337</td>
<td>( F = 2.61221 ) ( p = .0526 )</td>
</tr>
<tr>
<td>( \beta_{it} = -0.125578 ) ( (F = 3.108, p = .0795) )</td>
<td>( \beta_k = 0.064747 ) ( (F = 0.817, p = .3673) )</td>
<td>( \beta_l = -0.137178 ) ( (F = 3.721, p = .0552) )</td>
<td>( .01521 )</td>
<td></td>
</tr>
</tbody>
</table>
Productivity of Information Technology. The results from analysis of the monetary inputs on the aggregate sample show that the estimates of elasticity for all three variables are significant at the 0.05 level. This lends further support for the first hypothesis, that information technology is a productive factor in retailing. Not only is the elasticity estimate of information technology positive and significant, it is as large as the estimate of elasticity for capital. This indicates that the contribution of capital and information technology are nearly the same on the margin.

Returns to Scale. Included on the last column of Table 4.7 is an estimation of the passus coefficient for the Cobb-Douglas function. As previously discussed, Economies Of Scale (EOS) is defined as the percentage change in output, relative to a given percentage change in inputs. Economic theory suggests that, in an efficient market operating at equilibrium, firms should operate at constant returns to scale (Ingene 1984). The second hypothesis questions whether retailers are operating at long run equilibrium and optimal efficiency by testing the degree of homogeneity of the function. The results in Table 4.7 indicate that the passus coefficient is not significantly different from 1.0, indicating constant returns to scale. This lends initial support to the second hypothesis.

Translog Function Estimates. The elasticity estimates from the Cobb-Douglas function are relatively close to those of the translog function. As discussed previously, the partial F test of the difference between the Cobb-Douglas and translog functions is insignificant at the 0.05 level, indicating no statistical difference between the equations.
Marginal Product of Information Technology

As discussed in Chapter III, the marginal product of information technology was calculated as the first partial derivative of the production function with respect to information technology. Since both output (VA) and information technology (IT cost) are measured in dollars, the marginal product is interpreted as the number of dollars of output obtained by an additional dollar of an input factor.

The third hypothesis, that the marginal product of information technology is equal to 1.0, was tested by estimating the MP<sub>it</sub> for each observation and using a t-test. The results are shown in Table 4.8.

<table>
<thead>
<tr>
<th>TABLE 4.8</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEAN MARGINAL PRODUCTS</td>
</tr>
<tr>
<td>MP of IT</td>
</tr>
<tr>
<td>(t value for MP=1)</td>
</tr>
<tr>
<td>22.62</td>
</tr>
<tr>
<td>(5.6745)</td>
</tr>
</tbody>
</table>

The results in the first column suggest that there is a high positive return on the margin for the implementation of information technology. The marginal product of information technology is significantly higher than 1.0, indicating a lack of support for the third hypothesis. As seen in the second and third columns, the marginal products
of capital and labor are also significantly higher than expected. These results are further discussed in Chapter V.

Rate of Technical Substitution of Information Technology

The Rate of Technical Substitution (RTS) is the rate at which one factor can be substituted for another while maintaining the same level of output. Since both output (value added) and inputs (payroll, rent and information technology investment) are measured in dollar values, the RTS between any two factors of production should be equal to one if the market is efficient in allocating the inputs. Retailers should theoretically operate on the production function at the point where one dollar's worth of one factor can be substituted for a single dollar's worth of any other factor, as stated in the final set of hypotheses. Specifically, the market for information technology is efficient if the RTS between information technology and capital (H4a), and also between information technology and labor (H4b), are both equal to one.

The RTS between information technology and both Capital and Labor was calculated as the ratio of their respective marginal products. The results of these calculations and their respective statistical tests are shown in Table 4.9.
The results of the RTS analysis indicate a lack of support for the fourth set of hypotheses (H4a and H4b). The RTS of information technology with both labor and capital are significantly greater than 1.0 at the 0.05 level. These results are not surprising given the relationship between MP and RTS and the results of the MP analysis.

**Regression Results by SIC Using 2SLS**

Cobb-Douglas production functions were estimated using 2SLS for each SIC grouping as discussed previously. The results are shown in Table 4.10.
All three elasticities were significant in only two of the eight SIC categories (56 - apparel and 59 - miscellaneous). Neither of these two equations had relatively high $R^2$ values. As shown in other analyses of this type (Ingene 1982, 1985), the independent variables show high degrees of multicollinearity. The condition indices were 59.56, 47.36, 46.20, 47.50, 48.04, 52.87, 41.16, and 46.36 for SIC 52 through 59, respectively. As indicated by Hair et al. (1992), values greater than 30 signify multicollinearity problems. They suggest several methods of dealing with this none of which are appropriate for this analysis.
<table>
<thead>
<tr>
<th>SIC Code</th>
<th>Ln (IT INVEST)</th>
<th>Ln (Rent)</th>
<th>Ln (Payroll)</th>
<th>R Squared</th>
<th>Pass &amp; Coefficient</th>
<th>Sample Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>52 BUILDING</td>
<td>0.393416 (F = 9.09)</td>
<td>0.177178 (F = 0.49)</td>
<td>0.188290 (F = 1.95)</td>
<td>0.64113 (.60401)</td>
<td>0.758884 (t = -1.38)</td>
<td>33</td>
</tr>
<tr>
<td>53 GENERAL</td>
<td>-0.00707 (F = 0.08)</td>
<td>0.009461 (F = 0.01)</td>
<td>0.994421 (F = 43.75)</td>
<td>.81305 (.79148)</td>
<td>.996804 (t = -0.03)</td>
<td>30</td>
</tr>
<tr>
<td>54 FOOD</td>
<td>0.107036 (F = 0.70)</td>
<td>-0.01727 (F = 0.03)</td>
<td>0.914023 (F = 19.84)</td>
<td>.64715 (.62825)</td>
<td>1.003786 (t = 0.03)</td>
<td>60</td>
</tr>
<tr>
<td>55 AUTO</td>
<td>-0.15847 (F = 1.03)</td>
<td>0.088768 (F = 0.46)</td>
<td>0.516743 (F = 11.03)</td>
<td>.50328 (.46780)</td>
<td>.747032 (t = -1.72)</td>
<td>46</td>
</tr>
<tr>
<td>56 APPAREL</td>
<td>0.210041 (F = 4.52)</td>
<td>0.197105 (F = 5.50321)</td>
<td>0.565868 (F = 12.89)</td>
<td>.45664 (.43791)</td>
<td>.971014 (t = -0.22)</td>
<td>91</td>
</tr>
<tr>
<td>57 FURNITURE</td>
<td>0.11289 (F = 1.60)</td>
<td>0.225103 (F = 6.32)</td>
<td>0.778903 (F = 18.11)</td>
<td>.52728 (.50547)</td>
<td>1.116966 (t = 0.71)</td>
<td>69</td>
</tr>
<tr>
<td>58 EATING</td>
<td>0.520346 (F = 6.04)</td>
<td>-0.08685 (F = 1.19)</td>
<td>0.697137 (F = 24.48)</td>
<td>.51467 (.49713)</td>
<td>1.130625 (t = 1.06)</td>
<td>87</td>
</tr>
<tr>
<td>59 MISC</td>
<td>0.226409 (F = 3.47)</td>
<td>0.28243 (F = 7.74)</td>
<td>0.614988 (F = 13.27)</td>
<td>.54887 (.53295)</td>
<td>1.123827 (t = 0.93)</td>
<td>89</td>
</tr>
</tbody>
</table>
As stated by Gujarati (1988, p. 289), it can be shown that "even if multicollinearity is very high ... the OLS estimators still retain the property of BLUE" (Best Unbiased Linear Estimates). He further shows that both the coefficient and standard error estimates are unbiased under conditions of high multicollinearity. However, he also indicates that, although unbiased, the variance of the estimators is likely to be high and therefore the coefficients unstable. This is further discussed in Chapter V.

As indicated above, the results are somewhat unstable. Four of the eight elasticity of information technology estimates are significant. This neither refutes nor supports the first hypothesis. The sixth column includes estimates of the *passus coefficient* and its respective t-test for equality to one. The statistical results indicate a tendency toward constant returns to scale in each of the analyses except SIC 55 - automotive stores, indicating general support for the second hypothesis. Although insignificant, SIC 52 shows a tendency towards increasing returns to scale. These results are likely an artifact of the measurement process, which included measures of store floor space and not necessarily of total space.

**Marginal Product of Information Technology by SIC**

Utilizing the results from Table 4.10, the marginal products were calculated using equation 3.18. The results were subjected to a t-test for equality to 1.0. The results are shown in Table 4.11. The table indicates which results were calculated
using regression coefficients found to be insignificant in the regression estimations.

These results need to be treated with caution.

TABLE 4.11

MEAN MARGINAL PRODUCT USING MONETARY INPUT MEASURES

<table>
<thead>
<tr>
<th></th>
<th>MP of IT (t value for MP=1)</th>
<th>MP of Labor (L) (t value for MP=1)</th>
<th>MP of Capital (K) (t value for MP=1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIC 52</td>
<td>66.65</td>
<td>0.61 (^1)</td>
<td>2.91 (^1)</td>
</tr>
<tr>
<td>BUILDING</td>
<td>(1.89)</td>
<td>(-4.64)</td>
<td>(3.09)</td>
</tr>
<tr>
<td>SIC 53</td>
<td>-0.35 (^1)</td>
<td>3.18</td>
<td>0.39 (^1)</td>
</tr>
<tr>
<td>GENERAL</td>
<td>(-11.23)</td>
<td>(6.87)</td>
<td>(-2.67)</td>
</tr>
<tr>
<td>SIC 54</td>
<td>8.72 (^1)</td>
<td>6.15</td>
<td>-0.29 (^1)</td>
</tr>
<tr>
<td>FOOD</td>
<td>(2.07)</td>
<td>(2.78)</td>
<td>(-32.05)</td>
</tr>
<tr>
<td>SIC 55</td>
<td>-12.30 (^1)</td>
<td>4.06</td>
<td>2.18 (^1)</td>
</tr>
<tr>
<td>AUTO</td>
<td>(-2.37)</td>
<td>(3.90)</td>
<td>(1.80)</td>
</tr>
<tr>
<td>SIC 56</td>
<td>275.7</td>
<td>2.34</td>
<td>3.07</td>
</tr>
<tr>
<td>APPAREL</td>
<td>(1.03)</td>
<td>(5.38)</td>
<td>(5.31)</td>
</tr>
<tr>
<td>SIC 57</td>
<td>5.15 (^1)</td>
<td>3.28</td>
<td>3.69</td>
</tr>
<tr>
<td>FURNITURE</td>
<td>(5.56)</td>
<td>(4.76)</td>
<td>(3.90)</td>
</tr>
<tr>
<td>SIC 58</td>
<td>68.00</td>
<td>2.36</td>
<td>-2.10 (^1)</td>
</tr>
<tr>
<td>EATING</td>
<td>(3.57)</td>
<td>(7.34)</td>
<td>(-7.01)</td>
</tr>
<tr>
<td>SIC 59</td>
<td>11.55</td>
<td>2.46</td>
<td>32.81</td>
</tr>
<tr>
<td>MISC</td>
<td>(6.14)</td>
<td>(6.58)</td>
<td>(1.11)</td>
</tr>
</tbody>
</table>

\(^1\) - Values are calculated using insignificant coefficients from the 2SLS regression and should be interpreted with care.

The results of the tests for \(MP_x\) equal to 1.0 are all significant except for SIC 56 - apparel stores. Four of the tests are disregarded because they are calculated using
insignificant regression coefficients. The final results show that three of the four
remaining tests are significantly different than expected, indicating a further lack of
support for the third hypothesis. Also, as shown in Table 4.11, the marginal products
of both capital and labor are reasonably stable, but still higher than expected.

**Rate of Technical Substitution of Information Technology by SIC**

The RTS between information technology and the other factors was calculated
as the ratio of their respective marginal products. A t-test for RTS equal to 1.0 was
then conducted. The results of this analysis are shown in Table 4.12. It should be
noted that several of these values, as marked, were calculated utilizing insignificant
results and were therefore ignored.

The results of the RTS analysis indicate that only one of the values is not
significantly different from 1.0 at the .05 level (RTS of labor for information
technology in SIC 56). Due to the relatively high value of this RTS (137.6), it is
suggested that the insignificance is due to an inflated standard error resulting from
multicollinearity. Further analysis suggests that several outliers cause this variable to
be high, both in terms of the mean and variance. The four remaining RTS estimates
are all significantly higher than expected. This adds to the current lack of support for
the fourth set of hypotheses.
TABLE 4.12
MEAN RATE OF TECHNICAL SUBSTITUTION
USING MONETARY INPUT MEASURES

<table>
<thead>
<tr>
<th>SIC</th>
<th>RTS of Labor for IT (t value for RTS = 1)</th>
<th>RTS of Capital for IT (t value for RTS = 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>52</td>
<td>46.28 ( ^1 ) (2.90)</td>
<td>7.68 ( ^1 ) (3.22)</td>
</tr>
<tr>
<td>BUILDING</td>
<td></td>
<td></td>
</tr>
<tr>
<td>53</td>
<td>-0.07 ( ^1 ) (-50.44)</td>
<td>-3.54 ( ^1 ) (-4.68)</td>
</tr>
<tr>
<td>GENERAL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>54</td>
<td>4.14 ( ^1 ) (1.80)</td>
<td>-67.10 ( ^1 ) (-1.78)</td>
</tr>
<tr>
<td>FOOD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>55</td>
<td>-3.85 ( ^1 ) (-3.06)</td>
<td>-15.00 ( ^1 ) (-1.98)</td>
</tr>
<tr>
<td>AUTO</td>
<td></td>
<td></td>
</tr>
<tr>
<td>56</td>
<td>137.6</td>
<td>5.63</td>
</tr>
<tr>
<td>APPAREL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>57</td>
<td>2.52 ( ^1 ) (3.90)</td>
<td>2.47</td>
</tr>
<tr>
<td>FURNITURE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>58</td>
<td>38.25 ( ^1 ) (3.72)</td>
<td>-122.00 ( ^1 ) (-2.29)</td>
</tr>
<tr>
<td>EATING</td>
<td></td>
<td></td>
</tr>
<tr>
<td>59</td>
<td>7.74</td>
<td>5.34</td>
</tr>
<tr>
<td>MISC</td>
<td>(4.89)</td>
<td>(4.85)</td>
</tr>
</tbody>
</table>

\( ^1 \) values are calculated using insignificant coefficients from the 2SLS regression and should be interpreted with care.
Weighted Input Measures

The third major section of the results consists of production function estimations using weighted composite measures of inputs. The weights for the input variables were derived using the following formula:

\[
Weight_i = \frac{\text{Market Value}_i}{\sum (\text{Market Value}_i)/i}
\]

Composites of each variable were estimated by multiplying the weights by the number of units of each type of input and summing the results for each of the three inputs. These values represent a composite value of the amount of labor, capital, and information technology for estimation of a production function. A description of the weighted composites is shown in Table 4.13.

<table>
<thead>
<tr>
<th>Sample</th>
<th>(IT_w)</th>
<th>(L_w)</th>
<th>(K_w)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregate Sample</td>
<td>9.95</td>
<td>24.519</td>
<td>13352.622</td>
</tr>
<tr>
<td>52 - Building</td>
<td>10.78</td>
<td>14.645</td>
<td>9943.826</td>
</tr>
<tr>
<td>53 - General Merch</td>
<td>22.04</td>
<td>78.067</td>
<td>90947.787</td>
</tr>
<tr>
<td>54 - Food Stores</td>
<td>14.09</td>
<td>46.861</td>
<td>20318.027</td>
</tr>
<tr>
<td>55 - Automotive</td>
<td>11.98</td>
<td>25.958</td>
<td>14999.241</td>
</tr>
<tr>
<td>56 - Apparel</td>
<td>7.20</td>
<td>10.343</td>
<td>5856.413</td>
</tr>
<tr>
<td>57 - Furniture</td>
<td>9.22</td>
<td>7.781</td>
<td>5699.058</td>
</tr>
<tr>
<td>58 - Eating/Drinking</td>
<td>7.86</td>
<td>35.549</td>
<td>5266.232</td>
</tr>
<tr>
<td>59 - Miscellaneous</td>
<td>7.03</td>
<td>10.514</td>
<td>4278.466</td>
</tr>
</tbody>
</table>
Regression Results for Aggregate Sample with Weighted Measures

A Cobb-Douglas production function was estimated for the full sample using OLS and the weighted measures. The results are shown in Table 4.13. The coefficients can no longer be interpreted as elasticity estimates due to the unique measurement scheme used in this analysis. Each unit is weighted by its approximate market value and, therefore, is not interpretable as either pure monetary or physical units. Instead, the coefficients are interpreted as the ratio of the percentage change in value added to the percentage change in the number of units weighted by value. In the same fashion, the passus coefficient can no longer be interpreted using the classic definition of the degree of homogeneity.

The results of the Cobb-Douglas estimation using weighted input variables indicate that all three inputs (labor, capital, and information technology) are productive. This lends additional support for the first hypothesis, the productivity of information technology in retailing. Contrary to earlier findings, the analysis also indicates that retailers are operating at diseconomies of scale. However, as noted above, the traditional definition of economies of scale is not appropriate when using weighted variables.
### TABLE 4.14

**OLS RESULTS FOR AGGREGATE SAMPLE WITH WEIGHTED MEASURES**

**COBB-DOUGLAS** - Output \( (Q) = \beta_0 (K^{\beta_k})(L^{\beta_l})(IT^{\beta_T}) \)

<table>
<thead>
<tr>
<th>IT(^1)</th>
<th>Capital(^1)</th>
<th>Labor(^1)</th>
<th>R Squared (R Squared Adjusted)</th>
<th>Passus Coefficient (t-ratio for Passus = 1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ln (IT INVEST)</td>
<td>Ln (Rent)</td>
<td>Ln (Payroll)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \beta_n = 0.188855 )</td>
<td>( \beta_k = 0.243118 )</td>
<td>( \beta_l = 0.672206 )</td>
<td>( .60777 )</td>
<td>( 1.104179 )</td>
</tr>
<tr>
<td>(( F = 17.079, p &lt; .0001 ))</td>
<td>(( F = 37.667, p &lt; .0001 ))</td>
<td>(( F = 189.405, p &lt; .0001 ))</td>
<td></td>
<td>(( t = 2.455 ))</td>
</tr>
</tbody>
</table>

**TRANSLOG** - Output \( (Q) = \beta_0 (K^{\beta_k})(L^{\beta_l})(IT^{\beta_T}) e^{\beta_{12}(L) + \beta_{21}(K) + \beta_{12}(IT)} \)

<table>
<thead>
<tr>
<th>IT(^1)</th>
<th>Capital(^1)</th>
<th>Labor(^1)</th>
<th>R Squared (R Squared Change from Cobb-Douglas)</th>
<th>Partial F test of ( e^{\beta_{12}(L) + \beta_{21}(K) + \beta_{12}(IT)} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \beta_n = 0.168729 )</td>
<td>( \beta_k = 0.242167 )</td>
<td>( \beta_l = 0.678465 )</td>
<td>( .6079 )</td>
<td>( F = 0.08700 )</td>
</tr>
<tr>
<td>(( F = 7.548, p = .0062 ))</td>
<td>(( F = 30.881, p &lt; .0001 ))</td>
<td>(( F = 108.191, p &lt; .0001 ))</td>
<td></td>
<td>(( p = .9672 ))</td>
</tr>
<tr>
<td>( \beta_{12} = 0.003471 )</td>
<td>( \beta_{21} = -0.0000001 )</td>
<td>( \beta_{12} = -0.00003744 )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(( F = 0.236, p = .6270 ))</td>
<td>(( F = 0.017, p = .8956 ))</td>
<td>(( F = 0.055, p = .8149 ))</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Regression Results by SIC Breakdown

Estimation of a Cobb-Douglas production function using OLS was also completed for each individual SIC sub-sample. The results are shown in Table 4.15. As with the previous analysis, the coefficients cannot be interpreted as estimates of elasticity. Also, the estimated passus coefficient cannot be interpreted as the degree of homogeneity with reference to economies of scale.

Three of the eight coefficients of the information technology variable are significant, indicating the first lack of support found for the first hypothesis. Also, the passus coefficient is significantly different from that expected in half of the cases. This neither supports, nor detracts support, from the second hypothesis. The results are discussed in Chapter V.
### TABLE 4.15

COBB-DOUGLAS FUNCTION ESTIMATIONS (OLS) WITH WEIGHTED MEASURES

<table>
<thead>
<tr>
<th>SIC</th>
<th>Ln (IT weighted)</th>
<th>Ln (Labor weighted)</th>
<th>Ln (Capital weighted)</th>
<th>R Squared (R² Adjusted)</th>
<th>Passus Coefficient</th>
<th>Sample Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>52</td>
<td>0.492260</td>
<td>0.317489</td>
<td>0.419661</td>
<td>.63258</td>
<td>1.22981</td>
<td>33</td>
</tr>
<tr>
<td>BUILDING</td>
<td>(F = 8.467, p = .007)</td>
<td>(F = 2.250, p = .1444)</td>
<td>(F = 6.83, p = .0141)</td>
<td>(.59457)</td>
<td>(t = 1.657)</td>
<td></td>
</tr>
<tr>
<td>53</td>
<td>-0.033515</td>
<td>1.041968</td>
<td>-0.110468</td>
<td>.78801</td>
<td>.897985</td>
<td>30</td>
</tr>
<tr>
<td>GENERAL</td>
<td>(F = 0.031, p = .861)</td>
<td>(F = 24.3, p &lt; .0001)</td>
<td>(F = 0.549, p = .465)</td>
<td>(.76335)</td>
<td>(t = -0.685)</td>
<td></td>
</tr>
<tr>
<td>54</td>
<td>0.019159</td>
<td>0.703585</td>
<td>0.294270</td>
<td>.65868</td>
<td>1.017014</td>
<td>64</td>
</tr>
<tr>
<td>FOOD</td>
<td>(F = 0.014, p = .906)</td>
<td>(F = 12.2, p = .0009)</td>
<td>(F = 3.00, p = .0884)</td>
<td>(.67311)</td>
<td>(t = 0.165)</td>
<td></td>
</tr>
<tr>
<td>55</td>
<td>-0.157193</td>
<td>0.724643</td>
<td>0.171567</td>
<td>.49143</td>
<td>.739017</td>
<td>48</td>
</tr>
<tr>
<td>AUTO</td>
<td>(F = 0.758, p = .389)</td>
<td>(F = 15.1, p = .0003)</td>
<td>(F = 1.599, p = .213)</td>
<td>(.45676)</td>
<td>(t = -1.74)</td>
<td></td>
</tr>
<tr>
<td>56</td>
<td>0.140904</td>
<td>0.730551</td>
<td>0.223651</td>
<td>.46043</td>
<td>1.105106</td>
<td>93</td>
</tr>
<tr>
<td>APPAREL</td>
<td>(F = 1.858, p = .176)</td>
<td>(F = 28.6, p &lt; .0001)</td>
<td>(F = 5.912, p = .017)</td>
<td>(.44224)</td>
<td>(t = 0.079)</td>
<td></td>
</tr>
<tr>
<td>57</td>
<td>0.195491</td>
<td>0.960018</td>
<td>0.355005</td>
<td>.62475</td>
<td>1.510514</td>
<td>67</td>
</tr>
<tr>
<td>FURNITURE</td>
<td>(F = 4.172, p = .045)</td>
<td>(F = 34.5, p &lt; .0001)</td>
<td>(F = 11.17, p = .001)</td>
<td>(.60688)</td>
<td>(t = 3.206)</td>
<td></td>
</tr>
<tr>
<td>58</td>
<td>0.397640</td>
<td>0.604748</td>
<td>-0.079442</td>
<td>.48594</td>
<td>.922946</td>
<td>86</td>
</tr>
<tr>
<td>EATING</td>
<td>(F = 10.21, p = .002)</td>
<td>(F = 23.8, p &lt; .0001)</td>
<td>(F = 0.547, p = .462)</td>
<td>(.46713)</td>
<td>(t = -0.062)</td>
<td></td>
</tr>
<tr>
<td>59</td>
<td>0.143466</td>
<td>0.804699</td>
<td>0.273062</td>
<td>.52734</td>
<td>1.221227</td>
<td>92</td>
</tr>
<tr>
<td>MISC</td>
<td>(F = 1.590, p = .211)</td>
<td>(F = 27.5, p &lt; .0001)</td>
<td>(F = 6.074, p = .016)</td>
<td>(.51123)</td>
<td>(t = 1.742)</td>
<td></td>
</tr>
</tbody>
</table>
Chapter Summary

The results of the research effort were presented in this chapter. Table 4.16 summarizes the results of the statistical tests.

**TABLE 4.16**

**SUMMARY OF STATISTICAL TEST RESULTS**

<table>
<thead>
<tr>
<th>Functional Form</th>
<th>H1</th>
<th>H2</th>
<th>H3</th>
<th>H4a</th>
<th>H4b</th>
</tr>
</thead>
<tbody>
<tr>
<td>OLS w/ physical measures</td>
<td>Supported</td>
<td>Not Tested</td>
<td>Not Tested</td>
<td>Not Tested</td>
<td>Not Tested</td>
</tr>
<tr>
<td>OLS w/ monetary measures</td>
<td>Supported</td>
<td>Supported</td>
<td>Rejected</td>
<td>Rejected</td>
<td>Rejected</td>
</tr>
<tr>
<td>2SLS w/ monetary measures by SIC</td>
<td>50%</td>
<td>87.5%</td>
<td>87.5%</td>
<td>87.5%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>(4 of 8)</td>
<td>(7 of 8)</td>
<td>(7 of 8)</td>
<td>(7 of 8)</td>
<td>(8 of 8)</td>
</tr>
<tr>
<td></td>
<td>Support</td>
<td>Support</td>
<td>Reject</td>
<td>Reject</td>
<td>Reject</td>
</tr>
<tr>
<td>OLS w/ weighted measures</td>
<td>Supported</td>
<td>Rejected</td>
<td>Not Tested</td>
<td>Not Tested</td>
<td>Not Tested</td>
</tr>
<tr>
<td>OLS w/ weighted measures by SIC</td>
<td>37.5%</td>
<td>50%</td>
<td>Not Tested</td>
<td>Not Tested</td>
<td>Not Tested</td>
</tr>
<tr>
<td></td>
<td>(3 of 8)</td>
<td>(4 of 8)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Support</td>
<td>Support</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The first hypothesis, the productivity of information technology in retailing, was supported in the analysis using both physical and monetary input measures, but not when testing the hypothesis using weighted measures at the SIC level. The second hypothesis, constant returns to scale, was generally supported, with the exception of
the analysis using weighted measures at the aggregate level. The third hypothesis and
the fourth set of hypotheses both lack support from the results. These results are
interpreted and discussed in the fifth and final chapter of the research, Chapter V.
The final chapter will also include a discussion of the theoretical, methodological, and
managerial implications of the research.
CHAPTER V

DISCUSSION AND IMPLICATIONS OF RESULTS

Chapter IV presented the detailed results of the research. With a single exception the results supported the first and second hypotheses. The analysis of the third hypothesis and fourth set of hypotheses indicated that both should be rejected as they are currently stated. This chapter also includes a further discussion and interpretation of the results. Also, the results offer several implications which are further discussed, including theoretical, empirical, and managerial implications. The chapter will conclude the dissertation with a discussion of the limitations of the research effort and avenues for further development.

Interpretation of the Results

Nineteen statistical tests were conducted relating to the first hypothesis which suggest information technology is a productive factor in retailing. Three of these tests utilized the full sample and two sets of eight tests used SIC subsamples. These tests consisted of partial F tests on sets of regression coefficients and t-tests on single coefficients of the information technology variables. Of the 19 tests, nine refuted the assertion of information technology being a productive factor in retailing. Each of the
insignificant results occurred under conditions of high degrees of multicollinearity in
the data. The insignificance of these results is attributed to the lack of statistical power
due to relatively small sample sizes. While several methods were examined to
overcome the multicollinearity problem, each was deemed inappropriate because it
either changed the characteristics of the data, the interpretation of the results, or made
the subsequent testing of other hypotheses impossible. The author concludes that the
first hypothesis cannot be rejected on two bases. First, evidence indicates that the nine
insignificant coefficients resulted from inflated standard errors caused by high degrees
of multicollinearity. When tested on the aggregate sample, the statistical power
increased to the point of overcoming this problem and the coefficients exhibited a
strong tendency to support the first hypothesis.

The first hypothesis stated a concern widely expressed in the literature relating
to the lack of findings indicating productivity gains from the implementation of
information technology. The results indicate that information technology is a
productive factor in retailing. Information technology, combined with other factors of
production, can contribute toward the creation of output. However, support of this
hypothesis does not indicate that information technology is being efficiently utilized,
but only that it can be used to assist in the creation of output. The remainder of the
hypotheses examine the question of whether retailers are using information technology
efficiently.

The second hypothesis stated that retailers operate at constant returns to scale.
Of the 18 statistical tests of this hypothesis, 12 were found in agreement. All but one
of the tests rejecting the hypothesis were based on weighted data, which is not subject to the strict interpretation of the homogeneity of a production function. The findings of support for constant returns to scale in retailing are consistent with previous findings, which did not include an examination of information technology (Arndt and Olsen 1975; Lusch and Ingene 1979; Lusch 1980; Douit 1984; Ingene 1984).

The finding of constant returns to scale in retailing indicates that retailers utilize the combination of their inputs to create output in an optimal manner. Further, support for this hypothesis suggests that retailers are operating in a manner consistent with the assumptions of perfect competition. Both in the aggregate and in specific sectors, retailers are operating at optimal scale efficiencies.

The third hypothesis proposed that the marginal product of information technology should be equal to 1.0 when both inputs and output are measured as dollar values. Of the nine t-tests relating to this hypothesis, eight refuted the claim of an efficient market for information technology. Four of the nine tests were based on insignificant results from the regression analysis and were dropped from consideration. However, of the remaining five statistical tests, four still refuted the hypothesis. Overall, these results indicate a strong lack of support for the third hypothesis.

Marginal productivity theory suggests that retailers ought to exhaust the marginal product of inputs. In other words, retailers should add more inputs until the cost of additional inputs is equal to value of their respective output. The results suggest that retailers are gaining relatively more output per dollar's worth of input than they should at the margin. While the notion of positive gains from inputs is intuitively
appealing, this result suggests that retailers can achieve positive contribution margins from employing additional resources, specifically higher amounts of information technology. On the average, retailers can gain approximately $22 of gross margin by adding an additional dollar’s worth of information technology.

In addition, the results show that the marginal products of labor and capital were also higher than expected, again suggesting that positive gains in contribution margin can be achieved by increasing inputs. An examination of the relative divisibility of the factors indicates a possible explanation for these results. The results suggest that the lower the divisibility of a factor, the larger the marginal product. Theory suggests that retailers will continually add an input as long as it generates higher marginal returns than costs. However, the theory assumes that inputs are completely divisible and do not exist in large, indivisible units. This is nearly true for labor, where the retailer can add a single hour of labor by having an employee work longer or by adding part-time salespeople. This is exhibited in the results by the marginal product of labor being only slightly larger than expected. Acquiring additional space requires relocating, expanding into a neighboring space, or building. This is reflected by a relatively high marginal product for capital, signifying that retailers do not add space until marginal returns are exhausted. Lastly, adding more information technology requires not only blocks of capital investment, but also training, maintenance, and the specialized knowledge of the purchaser. The results suggest that retailers do not exhaust returns from investments in information technology.
The fourth set of hypotheses, along with the third hypothesis, was developed using the theory of marginal productivity. The last set of hypotheses suggested that the rate of technical substitution between information technology and other factors should be equal to 1.0 when both are measured in dollar units. Given the functional relationship between MP and RTS along with the rejection of the third hypothesis, it is not surprising that the fourth hypotheses were also rejected. Of the 18 statistical tests relating to these hypotheses, eleven were deemed inappropriate because their calculations resulted from insignificant regression coefficients. Six of the seven remaining tests reject the fourth set of hypotheses.

The results of testing the last set of hypotheses suggest that retailers can gain on the margin by substituting information technology for both labor and capital. Information technology can increase the efficiency of operations at a higher marginal rate than either capital or labor. While this indicates that retailers should replace workers and floor space with information technology, this suggestion would be misleading. Since retailers have not exhausted the returns on any of the three factors of production, the rate of technical substitution indicates only relative gains at the margin, instead of replacement rates. In other words, the results suggest that relatively higher gains can be made by implementing information technology than other factors. However, since all three factors have marginal products greater than 1.0, replacement of labor or capital using information technology would only tend to increase output while maintaining current inefficiencies. Instead, the results suggest that retailers
should increase information technology until its marginal output is exhausted, then reexamine their relative operational position.

The last three hypotheses tested the efficiency of the market for factors of production in retailing. The second hypothesis supported market efficiency, while the third and fourth rejected an efficient market for information technology. A conceptual examination of the hypotheses suggests that the differences arise because the second hypothesis tests the efficiency of the utilization of all factors of production simultaneously, while the other two examine the efficiency of information technology in isolation. The logical conclusion arises that retailers utilize the mix of their production factors relatively well, but problems arise in the utilization of any given factor in isolation.

Implications of the Results

There are several implications of the findings from this study. These will be divided into theoretical, empirical, and managerial implications. The implications for theory suggest extensions that need to be incorporated into the theory of the firm and marginal productivity theory before they are applied in a retail setting. This research has also uncovered several methodological considerations that need to be addressed in the future. Lastly, normative suggestions for retail managers are derived from the results of the study.
Theoretical Implications

The most important finding of this research is that information is a productive factor in retailing. This finding is consistent with Ferrero (1991, p. 4) who states that:

Managers throughout the world understand that information technology has become a factor of productivity on par with labor, land, materials, and equipment.

While not surprising, this finding is contrary to a great deal of anecdotal evidence and speculation in the popular business press (Diebold 1990; Davis 1991; Levy 1993; Labbe 1993). Indeed, the results suggest that information technology contributes as much on the margin as spending on additional selling space. This suggests that the estimation of a production function for retailers must include information in some form, as discussed in the next section, to be sufficiently identified. The previous practice of omitting information from analysis casts doubt on previous findings of the magnitude of the elasticity of labor and capital. Also, serious doubts are cast on the traditional economic assumption of free and perfect information. The results suggest that researchers, particularly economists, who operate under this assumption could come to erroneous or, at a minimum, incomplete conclusions. The degree of error in research conclusions is proportional to the degree of dependence of the analysis on assumptions and the accuracy of these assumptions. In this case, there is strong renunciation of the perfect information assumption. Therefore, to the degree that research efforts rely on this assumption for their conclusion, there exists the likelihood
of error. Analysis that uses perfect information as a simplifying assumption is likely to result in simplistic results. This conclusion is based on a common warning in nearly all books on research methodology: "garbage in, garbage out," often referred to as the GIGO principle.

The results of the study also suggest that retailers may be under-utilizing information technology. One possible explanation for this is the indivisibility of production factors. As indicated earlier, the marginal product is higher for factors that are not easily added on the margin. Thurik and Van der Wijst (1984) suggest that marginal increases in labor are relatively easily employed in the form of part time labor. Less easily employed are greater amounts of capital in the form of retail selling space. It is also difficult to add small amounts of additional information technology to a store. This is reflected by the relative ranks of the marginal product values, lending support to the proposition that the indivisibility of factors causes the marginal products to be greater than expected. This suggests that theory needs to relax the traditional assumption of a mathematically continuous production function and incorporate the degree of factor divisibility to accommodate kinked or discontinuous production functions.
Empirical Implications

Two major empirical implications arise from this study relating to research design issues. First, productivity analysis of this type requires large samples to overcome problems with multicollinearity. While this finding is not new (Ingene 1982, 1984, 1985), it suggests that a continuing problem exists for which the only current solution is an increase in statistical power. Ingene (1984) overcame multicollinearity through the use of ridge regression. However, this method results in slightly biased coefficients (Gujarati 1988; Greene 1990). While not a major concern in Ingene's analysis, this study used the coefficients in subsequent calculations which would have compounded the slight bias into a major problem. Future researchers need to be aware of this problems and either invent new ways to deal with it or ensure statistical power sufficient to overcome it.

Results by Lusch and Ingene (1979) suggest that both monetary and physical measures of retail inputs perform equally well. This research extends this result to include the use of information technology. The results suggest that the elasticities of labor, capital, and information technology are not significantly different whether monetary or physical measures are used. Also, monetary measures exhibit unique characteristics that allow an examination of marginal productivity theory. The third set of measures, physical units weighted by market values, performed relatively poorly. Added to this is the fact that weighted measures are difficult to interpret in the context of elasticity, returns to scale, marginal products, and the rate of technical substitution.
While weighted measures allow the testing of the productivity of the factor, other uses of this type of measure should be avoided. Overall, the conclusion is reached that monetary measures exhibit several desirable characteristics for measurement of production factors, especially with regard to the measurement of information technology due to the lack of consistency of standard physical units of measure.

Managerial Implications

Several important implications for the retail manager arise from this study. First and foremost is that the manager can and should utilize information technology to increase the productivity of a store. As indicated in the previous chapters, authors in the trade and business press have suggested that investments in information technology are unproductive. The results of this study directly contradict these suppositions. In the aggregate, the dollar elasticity of information technology is slightly higher than capital. However, this is not to say that retail managers should invest heavily in information technology without careful analysis of the potential costs and gains. The results indicate that many stores not only fail to benefit from information technology, but are sometimes made less competitive. Therefore, managers need to be cognizant of unanticipated costs of information technology in terms of training, specialized personnel, continual updates, basic maintenance, and opportunity costs during downtime.
The average values of the marginal products obscure a very important fact -- there is a high variance of success in the implementation of information technology. The estimated marginal product is near zero ($0.01) for a few stores, indicating almost no return from the implementation of information technologies. Other stores have achieved significant gains, with the estimated marginal product of information technology well above $100. This indicates that not all retailers are successful in their attempts to improve performance through implementation of information technology, while others have reaped substantial gains.

As with any business investment, retailers need to be sure that they are obtaining the highest possible return from information technology. This includes a continual examination of the investment and return to ensure a sufficient payback on investment. Perhaps even more importantly, the retailers should be realistic about expected returns from investing in information technology before the investment is made. While the vendor is likely to quote figures of how other retailers have improved performance, each retail manager should examine the potential for both short-term and long-term gains in productivity before investing in information technology.

At the margin and under current operations in this market, it takes an average of approximately one dollar of information technology to replace 10 dollar’s worth of labor. Likewise, slightly less than 18 dollar's worth of capital are needed to be as productive as a single dollar of information technology. These results indicate that, at current levels, information can improve the efficiency of capital more than labor. One possible explanation is that retailers have exhausted most of the labor gains and have
not yet concentrated as much on using information technology to achieve gains in space efficiency. It is not surprising that retailers have concentrated on reducing labor due to the high relative expansion of labor costs.

Lastly, this study indicates that retailers can and should use information technology to increase the efficiency of both labor and space. The results indicate that there are gains in productivity to be had by improving the efficiency of both labor and space through the use of information technology. The relatively larger gains in space efficiency suggest that retailers need to concentrate more efforts on improving the allocation and use of retail floor space. It also suggests that information technology vendors should concentrate their efforts on designing more and better information technology that specifically address space utilization.

**Limitations and Future Research**

There are several limitations in this research. Each of the limitations carries an inherent opportunity to further our understanding through future research. The first limitation of this research design is the restricted external validity of the results to the U.S. retail population. This research design achieved high internal validity by limiting the geographic scope of the sample frame in order to restrict the effects of exogenous environmental variables on the results. Thus a trade-off between internal and external validity is made. In order to partially address this issue, the research design included an exhaustive cross-section of product retailers. However, it is paramount that this
research be replicated in other environments, preferably at the national or international level.

A second limitation of this research design is the general scope of the findings. This research is intentionally limited to a single subject: the productivity of information technology in retailing. Thus, other possible factors, such as energy or behavioral variables, were excluded from analysis. Limiting the research subject to a single area allows greater depth of examination and, therefore, greater contribution in a single area of interest. However, future research needs to expand the findings to include other potential variables affecting productivity. One possible area of concentration is the differences between retailers who achieve high productivity growth from implementing information technology and those who do not.

This research addressed the theoretical question of the productivity of information technology and the efficiency of the market. While the results of this study have managerial value, further studies need to expand the findings to the productivity of specific retail and information types. The research questions are not designed to lead to solutions which would solve specific managerial problems relating to information technology. Rather this research was developed from a general theoretical base to provide answers to specific research questions. The results provide general guidance for the retail industry. However, further studies need to address practitioners' needs by examining the productivity of each type of information technology as it relates to specific types of stores under unique environmental conditions.
Lastly, limitations arise from operational considerations. These limitations arise from the necessary use of dollar values in a production function and the use of a non-probability sample. The debate will likely continue over the correct measures for productivity analysis. In the interim, this research used well-defined and accepted measures that have been established in the literature. However, there is a need to derive more appropriate measures of retail output and inputs.

Summary

Comparative levels of productivity affect not only the competitive position of individual firms, but also affect the aggregate performance of economies. As the service sectors of industrialized economies continue to expand faster than other sectors, pressures for productivity growth in services will increase. Retailers are responding to this pressure by adopting a number of strategies, including the implementation of information technology. Also, as labor becomes relatively more expensive, firms have attempted to substitute other factors of production, such as IT, for labor.

Gains in productivity due to the adoption of information technology tend to be elusive. It is imperative that retailers, indeed all business managers, understand the extent to which investments in information technology help their businesses improve their current position. However, this is currently not the case. This study attempted to address this gap in knowledge by addressing the following questions: first, does information technology contribute to the productivity of retail institutions? Second, to
what degree can information technology be substituted for labor and capital in retailing? Finally, is the market efficient in allocating information technology?

Contrary to many observations in the popular press, the findings indicate that information technology is a productive factor in retailing. Indeed, the results suggest that information technology contributes as much on the margin as spending on additional selling space. Inconsistent with the suggestion that retailers may be spending too much on information technology, the results of the study suggest retailers are under-utilizing information technology, thus incurring an opportunity cost. Future research needs to attempt to validate these findings across geographical boundaries with different retail and information technology types.
APPENDIX

QUESTIONNAIRE
Dear Retailer,

Thank you for agreeing to participate in this study. This study is designed to determine the productivity of various assets in retailing. It is our hope that the results will contribute to the knowledge available to retailers concerning the use of assets such as technology. The study is being given to a limited number of retailers, consequently your response is very important. The purpose of this study is twofold. First, it is designed to teach students about marketing, specifically about the retail environment. Second, the data will be used for a doctoral dissertation. Please answer the questions to the best of your knowledge.

PURPOSE:

Information from the questionnaire will be used to:

1. assist the participants in better understanding the productivity of their assets (aggregate results will be provided to those who complete the questionnaire).

2. Increase the students knowledge of marketing in the retail environment;

3. complete a doctoral dissertation with the intent of determining the productivity of labor, capital and technology in retail institutions. However, information from this questionnaire will NOT be published or distributed;

RESULTS:

The results of the dissertation will be made available to you as a participant. Please realize that the results will NOT include data on any stores. In order to receive an outline of the results, please mail a business card and note to:

James Reardon
Department of Marketing
University of North Texas
P.O. Box 13677
Denton, TX 76203-6677
(817) 565-3338
CONFIDENTIALITY STATEMENT:

We realize that we are asking for some proprietary information. For this reason ALL information from this questionnaire is STRICTLY CONFIDENTIAL. We would not be asking for this information if it was not absolutely necessary to the study. Below please find a letter of confidentiality that is signed by myself, the chairman of the marketing department, and the student conducting the interview. Your name and phone has been requested for the sole purpose of verification of the students work. All paper will be destroyed after the data is entered into the computer.

We agree not to distribute or divulge the information contained in this questionnaire to anyone. Any results that are published or distributed in any form must be aggregated in such a manner as to not allow any person or institution to distinguish the nature of underlying data.

Dr. Ronald Hasty, Chairman, Department of Marketing

James Reardon, Doctoral Student, Marketing Department

Participating Student, Marketing Class
BASIC CHARACTERISTICS

1. SIC code (please check one).

   ______ 52 - Building Materials and Garden Supplies
   ______ 53 - General Merchandise Store (Dept and Variety)
   ______ 54 - Food Store (Grocery and specialty food)
   ______ 55 - Automotive Dealers and Service Stations
   ______ 56 - Apparel and Accessory Store
   ______ 57 - Furniture and Home Furnishings
   ______ 58 - Eating and Drinking Places
   ______ 59 - Miscellaneous Retailing

2. Which county is the store located in? (check one)

   ______ 1 Dallas
   ______ 2 Denton
   ______ 3 Tarrant

Which of the following best describes your store

3. Affiliation (check one)

   ______ 1 Independently affiliated (single outlet)
   ______ 2 Chain store (multiple locations)
   ______ 3 Franchise

4. Ownership (check one)

   ______ 1 Single owner
   ______ 2 Partnership
   ______ 3 Corporation

5. Management (check one)

   ______ 1 Owner managed
   ______ 2 Non-owner managed

6. ____________ How many years has this store been at its current location.
EMPLOYEES

7. __________ Total number of employees (Please include everyone)

8. __________ Number of Managers working for the store

9. __________ Number of FULL-TIME salespeople working for the store

10. __________ Number of PART-TIME salespeople working for the store

11. __________ Number of employees other than sales and management (stock etc.)

12. __________ Average number of hours worked PER WEEK by part-time employees

13. $ __________________ Average MONTHLY payroll
(please include all wages and salaries paid)

Store Size & Location

14. Which of the following best describes your location (Check one)
   ________ 1 Regional Shopping Mall
   ________ 2 Community Shopping Mall
   ________ 3 Strip Mall
   ________ 4 Neighborhood Mall
   ________ 5 Stand alone location
   ________ 6 Downtown location
   ________ 7 Factory Outlet Center
   ________ 8 Commercial Business District

15. __________ Total square foot of store

16. __________ Square feet of Administrative space (offices)

17. __________ Square feet of Receiving and Stocking Space (backroom)

18. $ ____________ Average monthly rent/lease amount in dollars
INFORMATION TECHNOLOGY

For each of the following, indicate the number that you have in your store.

19. _______ UPC Scanners (product barcode scanners)
20. _______ Electronic Cash Register
21. _______ Electronic credit card approval device
22. _______ FAX machines
23. _______ Barcode Printers (scales and other machines capable of printing)
24. _______ Computer terminals (other than laptops, PCs, or registers)
25. _______ Laptop Computers
26. _______ Personal or desktop computers
27. _______ Computer Printers
28. _______ Specialized (Custom) software programs
29. _______ Electronic check approval devices

Which of the following systems does your store have (check all that apply).

30. _______ Electronic mail system (E-mail)
31. _______ Electronic point of sales system (POS system)
32. _______ Management information system (MIS system)
33. _______ Computerized accounting/bookkeeping system
34. _______ Electronic Data Interchange (EDI) with vendors
35. _______ Electronic Quick Response (QR) system
36. _______ Computerized inventory tracking system
37. _______ Computerized buying/ordering system

39. $________________________ Please estimate how much money has been
    invested in information technology in your STORE
    (for all of the equipment and software marked
    above).

40. Q#__________ Indicate the question number of the technology type (above) that
    you believe contributes most to the productivity of your store.
PRODUCTIVITY MEASURES

How do you measure a salespersons productivity (check all that apply)?

41. Sales per time period
42. Margin attained
43. Profit added to store by employee
44. Number of transactions
45. Fulfilling expected behavior
46. Number of customer contacts
47. General attitude measures (aggressiveness, commitment, etc.)
48. Other

OPERATION MEASURES

49. YEARLY Gross Sales
50. Average sale per transaction (customer).
51. MONTHLY Utility bill
52. Yearly Advertising and Promotion Budget

Please answer one of the following (Q52 -Q54)

53. % Cost of Goods Sold (COGS) in percent (%)
54. Yearly Cost of Goods Sold (COGS) in $
55. Gross Margin in percent (%)
VERIFICATION INFORMATION

This information will ONLY be used to verify that the survey was completed in good order and make sure that other students do not ask you to participate for this survey again. None of the information on this page will be entered in the data files (including store name). The page will be removed and destroyed after the interview is verified.

Store Name

Location

Your Name

Phone Number

I want to THANK YOU for your participation. Your efforts in projects like this allow us to continue our education and thus give us the tools to generate knowledge that will useful to retailers.
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