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DOES INFORMATION TECHNOLOGY LEAD TO SMALLER FIRMS?

Erik Brynjolfsson
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Vijay Gurbaxani
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November 1989

CISR WP No. 211
Sloan WP No. 3142-90
CCS WP No. 106

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1930

Does Information Technology Lead to Smaller Firms?

Abstract

We examine the relationship between information technology capital and firm size using industry data for the entire U.S. economy. The results indicate that increased stocks of information technology are associated with significant decreases in firm size as measured by the number of employees. One explanation for this observations is that information technology enables reduced levels of vertical integration and our analysis of data for the U.S. manufacturing sector supports this explanation. We also find that the effects of information technology on organizations are most pronounced after a lag of two years. While the correlations we find cannot, of course, prove causality, the evidence is consistent with the hypothesis that information technology reduces transaction costs and coordination costs, enabling a shift from hierarchies to markets as a means of coordinating economic activity.

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1. Introduction: the research problem

Industrialized economies have recently entered a period of substantial organizational change. This transition has been likened to a "second industrial divide" (Piore and Sabel, 1984) or even the beginnings of a "post-industrial society" (Huber, 1984; and the studies reviewed therein). Among the postulated aspects of the transition are decreases in firm size, a shift to externally provided services, less hierarchical management processes within firms, a shift from mass production to flexible specialization, and increases in product and service variety.

The growing attention to these organizational changes has coincided with a rapid drop in the price of computing power (Gordon, 1987), significant increases in information technology (IT)[1] usage, and one infers, decreases in the price of information processing in general. Unfortunately, empirical research on the relationship between IT and organizational structure has produced few if any reliable generalizations. Indeed, when taken as a whole, the literature on IT impacts presents many contradictory results (Attewell and Rule, 1984).

We have recently been able to obtain detailed, economy-wide data on investments in IT in the U.S.,[2] enabling the use of econometric techniques to more

broadly study its impact. The principal aim of this paper is to perform an empirical examination of the impact of information technology on an important characteristic of economic organization: firm size as measured by the number of employees per firm. Because firm size is a key variable in many of the descriptions of a post-industrial economy as well as some of the theories on the impact of information technology, our results should also help illuminate the theoretical literature and put future work on a firmer empirical base. For instance, our findings that increases in information technology stock are associated not only with declines in employees per firm, but also with reduced vertical integration, support the theory that information technology reduces transaction costs (Brynjolfsson, Malone and Gurbaxani, 1988) and coordination costs (Malone, Yates and Benjamin, 1987; Malone and Smith, 1988).

The paper consists of five main sections. Section II provides background on the recent trends in IT usage and average firm size, and presents a brief discussion of the hypothesized relationship between these two variables. In section III, we explain the methodology and data used in this study. Section IV presents the basic results of the regressions and explores some explanations for the results. We conclude with some interpretations of the results and suggestions for further research in section V.

2. Background and hypotheses

2.1 Trends in the key variables

The data reveal two new trends in the last 10 years: 1) firm size, as measured by the number of employees in the average business establishment, has decreased substantially, and 2) the real stock of information technology has grown enormously. Whether or not the trends are related, the evidence for each independently is strong.

2.1.1 Firm size

Recent trends in firm size are widely reported. Piore (1986) cites data from County Business Patterns showing that the average establishment size has been decreasing since the 1970s, reversing an earlier trend towards ever-larger firms. Using a different data set, Birch (1979) had similar findings. His analysis of Dun & Bradstreet data revealed that the 27% of establishments under 20 employees accounted for 66% of all new jobs while the 46% of establishments that had over 100 employees generated only 12% of new jobs.

More recently, the trend has apparently intensified. The Bureau of Labor Statistics reports that from 1980 to 1986 firms of under 100 employees created six million new jobs while firms of over 1000 employees experienced a net loss of 1.5 million jobs.[3] The phenomenon is not unique to the U.S. but is also being experienced by other major industrial countries. As shown in graph 1, data from the UK, Germany, and the Netherlands also show a recent decrease in average firm size, despite increases until the early 1970s (Huppes, 1987). Carlsson (1988) also found a similar pattern in the

manufacturing sectors of other Western industrial countries and hypothesized that it was facilitated by computer-based technology.

Our examination of data reveals that the decrease in average establishment size is a function of two complementary trends: 1) in sectors that have many large firms, such as manufacturing, overall employment has not kept up with the growth in the number of firms, resulting in significant declines in average firm size, and 2) in sectors with typically smaller firms, such as services, employment has grown rapidly, while average firm size has remained small. (See graph 2).

A related trend, which is consistent with the above observations, is the increasing externalization or "decoupling" of business functions. This is manifested, for example, in a 45% increase from 1980 to 1986 in the use of outside contractors and consultants (Wall Street Journal, 1988). A detailed study of the metal-working industry found that amount of value added to shipments declined in 88 of 106 sectors between 1972 and 1982 and that this could be tied to increased use of information technology (Carlsson, 1988). In an article on how "value-adding partnerships" are supplanting vertically integrated companies, Johnston and Lawrence (1988) also argue that this phenomenon is partly enabled by information technology. Apparently, the wave of mergers and LBOs in the 1980s have not reversed this trend as highly leveraged firms have spun-off divisions and downsized even their core business (Scherer, 1988).

2.1.2 Information technology

Evidence of the increase in power and ubiquity of information technology is abundant even without looking at the statistics. A 1988 study found that there was one computer workstation for every five employees in surveyed companies (Nolan Norton, 1988). After controlling for depreciation and quality improvements, we find that the stock of IT has increased almost exponentially since 1970, from just over 1% of overall capital stock to nearly seven percent in 1985 (see graph 3). Each of the major business sectors shows the same accelerating trend toward increased use of IT. A category of equipment that was largely insignificant two decades ago is rapidly becoming very important.

Current investments in IT are estimated at 50% of all net capital purchases by business (Kriebel, 1988). Meanwhile, over half of the labor force is currently engaged in tasks that primarily involve information processing (Porat, 1977). Whatever effects of IT we detect today, these numbers are of sufficient magnitude to augur even greater effects in the near future.

2.2 Theoretical studies of IT and firm size

Theory suggests ways that IT can lead to larger firms as well as ways that IT can enable a reduction in firm size. A seminal article by Leavitt and Whisler (1958)

emphasized the effect of IT on reducing the costs of information transmission within the organization. One of the conclusions of this argument was that IT would lead to greater centralization and broader spans of hierarchical control. The principal-agent literature has also emphasized that the agency costs of hierarchy decrease in better information and monitoring by the principal (Jensen, 1983).[4] To the extent that the costs of centralization and agency are reduced by IT, one might expect to see more use of hierarchy and therefore larger firms.

This hypothesis contrasts with an analysis of IT's impacts based on transaction cost economics. According to Williamson (1975, 1985), production is brought under the governance of a single hierarchy in response to high transaction cost of organizing through the market. These "market failures" are caused by asset and site specificity, bounded rationality and uncertainty, impacted information, and small numbers bargaining. Information technology can be expected to mitigate these market failures and thus reduce the need to rely on hierarchies (Malone, Yates and Benjamin, 1987; Brynjolfsson, Malone and Gurbaxani, 1988).

A line of analysis by Malone and Smith which considers that information technology will reduce the costs of coordination both inside and outside the organization reached similar conclusions (Malone (1987) and Malone and Smith (1988)). They argue that because of the relatively larger coordination requirements of markets as opposed to hierarchies, reductions in coordination costs will be particularly beneficial for market

coordination. Accordingly, these models predict a decrease in the proportion of hierarchical coordination following investments in IT.

A related effect of information technology is that it might be expected to change the "minimum efficient scale" of production. For instance, Klein, Crawford and Alchian (1978), Grossman and Hart (1986) and Hart and Moore (1988) have emphasized that strong technological complementarities between assets can make markets inefficient and lead to common ownership of large, related sets of assets. However, if IT facilitates techniques like flexible manufacturing, it may decrease the specificity of assets, and thus transform hierarchical production to production organized through smaller units coordinated by markets.

In summary, the theoretical literature suggests that IT will reduce the costs of coordination both within firms and between firms. There is some reason to believe that the balance will shift towards more use of markets and smaller firms, but we cannot know, a priori, whether this effect exists and is of an economically significant magnitude. Furthermore, theorists have concentrated on the organizational forms which dominated the last century: markets and hierarchies. It is very possible that IT will enable new organizational forms with different characteristics. For instance, if large firms used information technology to set-up or simulate internal markets, average firm size might increase with information technology usage despite a greater reliance on markets.[5]

Fortunately, the question of how information technology affects firms size is subject to empirical investigation. Previously, a case study of the evolution of airline reservation systems (Malone, Yates and Benjamin, 1987), found that information technology was associated with increased market coordination. In this paper, we use econometric techniques to generalize those results to the U.S. economy as a whole.

3. Data and methodology

Our approach was to use available U.S. data to directly test the relationship between information technology stock and average firm size. The data are divided into eight sectors: agriculture; mining; durable goods manufacturing; non-durable goods manufacturing; transport and utilities; wholesale and retail trade; finance, insurance and real estate; and services. A series of regressions were then run on this data to identify the direction and magnitude of the relationship between IT and firm size, while controlling for total capital stock, industry and year. Several regression models were tested and data from alternative sources was also used to help validate the results.

3.1 The data

3.1.1 Information technology capital and total capital

Data from the Bureau of Economic Analysis (BEA) was used to derive figures for information technology stock and investments, and total capital stock by industry for each year. The BEA data classifies all economic activity in the United States into 61 industries. The data gathering methodology is described in Gorman et al. (1985). For each industry, total annual investments are measured in 27 asset categories. We use the category "office, computing and accounting machinery" for our IT figures and the sum of all categories for our total capital figures. Each asset category also has an associated quality-adjusted (hedonic) price deflator. By multiplying each investment by its associated deflator, nominal investments were converted into constant-dollar or "real" investments.[6] To derive capital stocks from investment flows, we used a modified Winfrey table which assumes a Normal distribution of equipment service lives around their expected mean lifetime as described in Gorman, et al. (1985). Thus each year, a percentage of existing equipment is eliminated based on its age while new stock is added from that year's investments.

3.1.2 Firm size: employees per establishment and per firm

Data on average establishment size is available from County Business Patterns' (CPB) annual summaries. The number of business establishments and number of employees is provided for each sector of the economy. Average establishment size is derived by dividing the latter by the former.[7] Because consistent data on establishment size were only available from 1977 to 1984, we used those years as the primary period of

our study.

Although the data from County Business Patterns is the most comprehensive census of establishments in the United States, another measure of firm size can be created from an alternative source: Compustat. Compustat maintains data on every publicly traded company, including number of employees and the SIC code of its principal line of business. Using the SIC code, we grouped all the companies into the same sectors of the economy used above and added up the number of employees and number of firms in each sector. This provided a second measure of firm size.

While this sample is presumably biased towards large firms (small firms are not usually publicly traded), it still includes over 2000 firms for each year. It also has two virtues. First, to the extent that "firms" differ from "establishments", the Compustat data measures firm size directly. Secondly, consistent Compustat data was available for a longer time period (1975-1985) than the CPB data. The only change from the previous specification was that the Compustat data included too few firms in the agricultural sector to provide a reliable statistic, so this sector was omitted from the regressions with Compustat data.

3.1.3 Vertical integration

We also explore the impact of IT on levels of vertical integration to help provide

insight into the mechanism by which IT affects firm size. Vertical integration is the degree to which multiple stages of production are combined under common ownership and coordinated within a single firm as opposed to a sequence of smaller firms (Gort, 1962). Our operational measure of this concept is the ratio of value added per firm to the total value shipped per firm.[8] This operationalization of vertical integration is a variation of the value added over sales measure originally proposed by Adelman (1951) and later modified to the current version by Tucker and Wilder (1977).

The data required to construct the vertical integration index is available from the Census of Manufacturers and the Annual Survey of Manufacturers for the manufacturing sectors of the economy. Unfortunately, no comparable data is available for other sectors of the economy. The data on vertical integration was analyzed for the period 1975 to 1985 (see Kambil, 1988) at the two digit SIC code level of aggregation. This distinguishes 20 different industries within the manufacturing sector.

3.1.4 Data grouping and dummy variables

The data for the dependent and explanatory variables was categorized by the Standard Industrial Classification (SIC) codes. The 61 industries used by the BEA were identified by their SIC codes and were then grouped into the eight sectors identified by CPB for the regressions on each of the measures of firm size and, as mentioned above, into 20 manufacturing industries for the vertical integration regressions.

We recognize that other trends may also have been important during the period under study. To control for time-specific effects like recessions or other trends unrelated to IT, we included dummy variables for each year. To control for effects specific to a particular sector, we included dummy variables for each of the industry sectors as well. Because the most natural interpretation of the both the dependent and explanatory variables is in terms of percentage-effect, the natural logarithm was taken of all the relevant variables.

3.2 Methodology

The basic technique used for analyzing the data was least-squares regression on panel data. The panel consisted of eight sectors observed from 1977 to 1984 for the CBP data and 1975 to 1985 for the other regressions on firm size. The vertical integration regressions discussed in section IV.D were on a panel of 20 manufacturing industries for the period 1975 to 1985.

Because the sectors were of different sizes, leading to possible heteroskedasticity, each observation on a sector was weighted by the size of the sector, as proxied by total employment in that sector that year.[9] The initial regressions revealed the potential presence of serial correlation so the generalized differencing correction for serial correlation was used in all regressions.[10]

3.2.1 The basic model

Our basic model allows for lags in the impact of IT on firm size and vertical integration. A number of authors have suggested that the effects of information technology may be particularly susceptible to lags (Baily and Gordon, 1988; Curley and Pyburn, 1982; Nolan Norton, 1988; Loveman, 1988). Lags are commonly observed in the assimilation of new technologies because it takes time to learn how to best use and apply the investment. Thus, in effect only some of the most recent years' investments will have their full impact on firm size.

The technique used to model the possibility that IT may be only partially effective at first is to include both ITSTOCK to measure the basic impact of IT, and the two most recent years of IT investments (ITINV), to measure the extent to which the effects of current investments are not immediately felt.[11] If learning is indeed taking place, ITINV and ITINV(-1) will have the opposite sign but be smaller in magnitude than ITSTOCK, thus reducing the effect of ITSTOCK for recent years. All of the impact of "effective" IT stock will be captured in the coefficient on ITSTOCK while the learning will be measured by the relative magnitude of the coefficient on ITINV.[12]

A measure of total capital stock in the sector, TOTSTOCK, was included to control for the fact that firm size will in general be larger when total capital stock is larger. Finally, effects specific to each industry and year were controlled for by including

two sets of appropriate dummy variables.

The basic model is specified as:[13]

$$\log(SIZE) = \beta_0 + \beta_1 * \log(ITSTOCK) + \beta_2 * \log(ITINV) + \beta_3 * \log(ITINV(-1)) + \beta_4 * \log(TOTSTOCK) + \Sigma \beta_i * INDUSTRY + \Sigma \beta_j * YEAR.$$

While there is likely to be some collinearity among the variables in this model, regression theory assumes that the independent variables are collinear and the least squares formulation is expressly designed to separate out the effects of each of the variables. However, while even severe collinearity does not violate any of the conditions required for accurate regression, it will in general lead to lower significance levels of the coefficients.

3.2.2 The lagged model

To better observe the overall time path of the relationship between IT stock and firm size, a series of separate regressions was run with IT lagged from zero to four years. Although none of these regressions individually will be able to capture any learning effect, taken together, they would be expected to show any changes in the effectiveness of IT over time.

The five regressions used to observe the time path of IT were:

$$\log(SIZE) = \beta_0 + \beta_1 * \log(\ ITSTOCK[-N]\ ) + \beta_2 * \log(\ TOTSTOCK\ ) + \Sigma\ \beta_i * INDUSTRY + \Sigma\ \beta_j * YEAR.$$

where $N \in \{0,...,4\}$, representing lags from 0 to 4 years.

3.3 Predicted signs of the coefficients

If information technology leads to smaller firms, then we would expect to see a negative sign on the coefficient of ITSTOCK in both models. Its magnitude will tell us how much a percentage change in IT stock will reduce firm size, all else being equal. In the basic model, the coefficient should be interpreted as the impact of one unit of "effective" IT capital and should thus be larger than the coefficient in any one of the lagged regressions.

The learning curve effect would lead to a positive sign on ITINV in the basic model, opposite the sign on ITSTOCK. Its magnitude should be less than the magnitude of the coefficient on ITSTOCK. Including ITINV will thus cancel a fraction of the most recent years' investments in IT because they have not yet reached their full effect on firm size.

In the lagged model, the impact of the IT stocks should be increasing for small

lags and then returning close to zero in distant years, exhibiting a concave pattern. The rise results as the technology is more fully exploited and the fraction of purchased IT stock that is "effective" increases. As the IT capital began to depreciate, the coefficient would fall.

Total capital stock is included primarily as a control variable. According to a transaction cost framework, industries which require large fixed capital investments will, ceteris paribus, have larger average firm size. The coefficient on TOTSTOCK should thus be positive.

The sector dummy variables control for systematic variations in firm size between sectors. For instance, manufacturing firms are typically much larger firms than firms in the service sector.

The time dummies capture year to year economy-wide changes such as recessions or external shocks. Because firms lay-off workers in recessions, average firm size would be expected to be lower in the recession years of 1980 and 1982 and higher in recovery years like 1984. If there is any overall trend in firm size that is not captured by the variables already in the model, this should also show up in the time dummies.

4. Results

4.1 Regressions on establishment size

As predicted by the hypothesis that IT leads to smaller firms, the coefficient on ITSTOCK is negative in all regressions. It is significant at the 0.01 level and its magnitude is large enough to be economically important. The coefficients on ITINV have the opposite sign of the ITSTOCK coefficients and are smaller in magnitude, as predicted by the learning curve hypothesis (see table 1).

The other variables are also as predicted. Total capital stock is positively correlated with establishment size. Dummy variables, though not shown here because of space limitations, were also as expected. For instance, manufacturing establishments were larger than service establishments and firm size was lowest in the recession year of 1982, after controlling for all the other variables. The unusually high R^2 is encouraging but perhaps somewhat misleading because the dummy variables "explain" the large intersectoral variations in firm size.[14]

Table 1: Basic Model

Dependent Variable: Establishment Size from CBP

VARIABLE	COEFFICIENT	T-STATISTIC
ITSTOCK	-0.1988***	(2.475)
ITINV	0.0297	(1.092)
ITINV(-1)	0.0743***	(2.593)
TOTSTOCK	0.4568**	(1.774)
R^2	0.999	
Durbin-Watson	1.677	

* significant at the 0.1 level (one-tailed test)
** significant at the 0.05 level (one-tailed test)
*** significant at the 0.01 level (one-tailed test)

In the series of lagged regressions, a slightly concave pattern of effects becomes evident as predicted (see table 2). The impact of IT is strongest after a lag of 2 years which shows establishment size declining by 8% for each 100% increase in real IT stock within the same sector. Thus, by itself, the coefficient on ITSTOCK is of sufficient magnitude to account for the change in the long-term growth trend in employees per establishment. From 1977 to 1985, real IT stock roughly tripled while establishment size decreased by about 20%, reversing its earlier upward trend.

Table 2: Model with ITSTOCK Lagged by Zero to Four Years

Dependent Variable: Establishment Size from CBP

N =	0	1	2	3	4
ITSTOCK(-N)	-0.0732	-0.0653*	-0.0824**	-0.0447	-0.0232
(t-statistic)	(1.282)	(1.470)	(1.802)	(1.028)	(0.555)
TOTSTOCK	0.8156***	0.7484***	0.5811***	0.6309***	0.6922***
(t-statistic)	(3.863)	(4.011)	(2.842)	(2.852)	(3.000)
R^2	0.999	0.999	0.999	0.999	0.999
Durbin-Watson	1.770	1.753	1.822	1.865	1.862

* significant at the 0.1 level (one-tailed test)
** significant at the 0.05 level (one-tailed test)
*** significant at the 0.01 level (one-tailed test)

The results of the regressions suggest that increased levels of information technology in a sector lead to a decrease in the average size of firms in that sector. The null hypothesis that IT does not affect firm size can be rejected at the 0.01 level of significance in the basic specification and at the 0.05 level when ITSTOCK is lagged by two years.

While the data from County Business Patterns is the most comprehensive available, we sought to confirm our findings by running the same regressions on a different data set to help guard against the possibility that our findings were somehow an artifact of the County Business Patterns data. The results of the confirmatory regressions are presented in the next section.

4.2 Are the results an artifact of the CBP data?

County Business Patterns, the source of our dependent variable, seeks to record every establishment in the country. It may be that information technology simply allows for better data gathering and small firms that were previously omitted are now included in the sample. Another possibility is that information technology reduces the size of individual establishments but enables firms to grow by adding more establishments. The CBP data would not detect such growth.

This alternative was examined by constructing a different measure of firm size from data available through Compustat as described in section II. The Compustat data is less susceptible to the same data gathering biases as the CBP data and furthermore, allows us to detect changes in the size of multi-establishment firms.

The results using this new source for the dependent variable are in table 3 and table 4. They show, in even stronger fashion, that increasing IT stock is associated with decreasing firm size. In the basic model and four out of five of the lagged regressions, ITSTOCK is significant beyond the 0.01 level. The lagged regressions show the same concave pattern of negative correlation between IT and firm size, again peaking after two years.[15]

Table 3: Basic Model

Dependent variable: Firm Size from Compustat

VARIABLE	COEFFICIENT	T-STATISTIC
ITSTOCK	-0.3253***	(4.824)
ITINV	0.0494*	(1.552)
ITINV(-1)	0.0962**	(2.578)
TOTSTOCK	0.8180***	(3.982)
R^2	0.999	
Durbin-Watson	2.075	

Table 4: Model with ITSTOCK Lagged by Zero to Four Years

Dependent Variable: Firm Size from Compustat

N =	0	1	2	3	4
ITSTOCK(-N)	-0.1429***	-0.1698***	-0.1934***	-0.1745***	-0.1302**
(t-statistic)	(4.140)	(4.743)	(5.192)	(4.019)	(2.596)
TOTSTOCK	1.0849***	1.0104***	0.8113***	0.6222***	0.6004***
(t-statistic)	(5.464)	(5.542)	(4.833)	(3.455)	(3.060)
R^2	0.999	0.999	0.999	0.999	0.999
Durbin-Watson	1.995	2.203	2.119	2.031	1.659

* significant at the 0.1 level (one-tailed test)
** significant at the 0.05 level (one-tailed test)
*** significant at the 0.01 level (one-tailed test)

The combined evidence of the preceding analysis of CBP and Compustat data

clearly indicates that increases in IT capital stock are associated with significant declines in the number of employees per firm. While this result is consistent with the hypothesis that IT leads to a reduction in the proportion of hierarchical coordination, IT might affect firms in other ways that could also lead to the relationship observed in the data. For instance, it is possible that firms continued to provide roughly the same scope of activities, but IT enabled them to do so with fewer employees. This could result if IT significantly increased the productivity of each worker directly or in some way facilitated the substitution of capital for labor.

While we cannot rule out either of these explanations, previous studies have not provided broad support for either proposition. A growing literature on what has come to be known as the "IT productivity paradox" finds that IT may not lead to significant increases in productivity (Loveman, 1988; Roach, 1989)[16]. Nor is there clear evidence that IT leads to the substitution of capital for labor, at least among clerks and managers (Osterman, 1986).[17] While it is beyond the scope of this paper to directly examine the IT productivity paradox, the positive coefficient on TOTSTOCK in the previous regressions as well as the results of additional regressions we ran on capital investments per firm suggest that IT is <u>not</u> leading to a significant substitution of capital for labor. In fact, total capital spending per firm actually decreased in industries with greater IT stock[18]

Accordingly, we focus our attention on the less widely examined possibility that IT

facilitates a relative increase in market coordination and a commensurate reduction in the scope of each individual firm's contribution to the value chain. This means that a series of smaller firms coordinated through markets undertake the activities previously managed by larger, integrated firms. This phenomenon could not only explain the decline in firm size we observed above, but also leads to the further prediction of reduced levels of vertical integration following increases in ITSTOCK.[19]

4.3 Information technology and vertical integration

The results of the regressions of information technology on the ratio of value added to sales, as shown below, support the hypothesis that one mechanism by which IT reduces firm size is by reducing the degree of vertical integration. Following increases in ITSTOCK, firms apparently find it feasible to divest functions that were previously too expensive to contract through the market. Once again, the impact of IT is strongest after a 2 year lag, when a 100% increase in IT is associated with a 3.1% decrease in vertical integration, with a significance in excess of 99%. The interpretation of the other variables is consistent with previous results.

Basic Model

Dependent Variable: Vertical Integration Index

VARIABLE	COEFFICIENT	T-STATISTIC
ITSTOCK	-0.0454 ***	(3.449)
ITINV	0.0268 ***	(3.867)
ITINV(-1)	0.0180 ***	(2.593)
TOTSTOCK	0.0537 **	(2.020)
R^2	0.953	
DURBIN-WATSON	1.760	

MODEL WITH ITSTOCK Lagged by Zero to Four Years

Dependent Variable: Vertical Integration Index

N=	0	1	2	3	4
ITSTOCK(-N)	-.019	-0.030	-0.031	-.024	-0.23
	T=1.134	T=2.50	T=3.15	T=2.60	T=2.67
	**	***	**	**	
TOTSTOCK	.096	0.106	O.104	0.093	0.090
	T=3.325	T=4.11	T=4.37	T=4.07	T=4.03
	***	***	***	***	***
R^2	0.94	0.94	0.94	0.94	0.94
DURBIN-WATSON	1.827	1.85	1.84	1.85	1.84

** significant at 0.05 level (two tailed test)
*** significant at the 0.01 level (two tailed test)

5. Conclusion

5.1 Summary

Using data from different sources, we have been able to clearly document a relationship between increased levels of information technology usage and smaller firm size. The decline in firm size is greatest with a lag of two years following investments in information technology, suggesting that the impacts of the new technology are not fully felt immediately. This finding may shed light on earlier studies which found little or no impact of IT in the same year that the investments were made.[20]

We also find evidence that the decline in firm size is at least partly explained by a relative increase in reliance on market coordination following IT investments, in accordance with earlier theory. Not only does vertical integration decline following IT investments, but the Compustat data, which allowed for multi-establishment firms showed a greater decline in firms size following IT investments than did the data based on single establishments.

It is worth noting that alternative explanations for the decline in firm size in this

period, such as increased international competition, would not directly explain the strong correlation we found with increased stocks of information technology. However, we cannot rule out more complex relationships. For instance, if some third trend in the economy is associated with both increased IT usage and with smaller firm size after a brief lag, it could produce the correlation we found in our regressions.

5.2 Future research

In this paper, we have focused on changes in firm size associated with IT investments within the same sector or industry. However, to the extent that IT enables the externalization of services, it may be contributing to the shift in employment from the manufacturing sector to the service sector. Because the service sector generally has smaller firms, such a shift would exacerbate the trend we identified in this study. An examination of this possibility would be a fruitful direction for future research.

Secondly, in interpreting our results we have largely presumed a dichotomy between markets and hierarchies. Perhaps some of the most interesting effects of information technology will be the enabling of new organizational forms such as "networks" (Antonelli, 1988; Piore, 1988), "ad-hocracies" (Toffler, 1982) or more complex forms. Future research should seek to identify and where possible quantify these new forms in order to establish whether, how, and why IT affects their implementation.

This paper has examined the relationship between information technology stock and a key indicator of the restructuring of the American economy, firm size. While IT constituted less than 7% of all capital stock in the period we examined, current net investment in IT amounts to 50% of net increases capital stock (Kriebel, 1988). This trend, combined with the relationship between IT and firm size, suggests that the American economy may see even more radical restructuring in the next decade.

Notes

1. We will generally use the terms "information technology" and "IT" as shorthand for the Bureau of Economic Analysis (BEA) category "Office, Computing and Accounting Machinery", which is comprised primarily of computers. Other authors use slightly different definitions but the basic trends are similar regardless of exact specification.

2. This data was compiled by Lou Gorman at the BEA and for the first time includes reasonably accurate hedonic price deflators for the computer industry. Because information technology has experienced such large annual performance improvements, old data which did not take quality changes into account could be severely misleading.

3. The data from the Bureau of Labor Statistics was reported in a chart in the Wall Street Journal on April 27, 1988, p.29, which also showed that intermediate size classes showed employment gains inversely proportional to their size. The data from County Business Patterns cited by Piore and the data compiled by David Birch refer to establishments, several of which are sometimes owned by a single corporation.

4. A less noted feature of agency analysis is that this result may be reversed when improved information is provided to the agent as well as, or instead of, to the principal (Brynjolfsson, 1989).

5. In a field study of 13 manufacturing firms, Eccles and White (1988) found that the use of transfer prices between divisions in the same firm was a very common alternative to pure "price" or "authority" mechanisms.

6.6. The deflator for information technology was actually an "inflator". A dollar bought more IT each year than it did the year before.

7. It should be noted that strictly speaking, establishments are not equivalent to firms, although the vast majority of firms consist of a single establishment as defined in CBP. A study by Carlsson (1988) found that the correlation between changes in the number of establishments and the number of firms in a sample of manufacturing industries was over 97%.

8. The value of industry shipments is defined as the amount received on net receivable selling value, f.o.b. plant, after discounts and allowances, and excluding freight charges and excise taxes. Value added by manufacture is derived by first converting the value of shipments to the value of production by adding in the ending inventory in finished goods and work in process, and subtracting the beginning inventory. The cost of materials, supplies, containers, fuels, purchased electricity, and contract work is subtracted from the value of production to obtain the value of manufacture. The ratio of value added by manufacture to shipments will increase monotonically as the degree of vertical integration increases. Changes in reporting inventories to the LIFO method beginning in 1982, make value added

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