IS THERE A PRODUCTIVITY PARADOX AT THE REGIONAL LEVEL?
AN EMPIRICAL STUDY OF THE GROWTH CONTRIBUTION OF IT CAPITAL STOCK AT THE STATE-LEVEL IN THE UNITED STATES BETWEEN 1977 AND 1997

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Abstract - *This study analyzes information technology embodied in the stock of capital. A panel dataset is constructed for the 50 states plus the District of Columbia, covering 52 industry categories from 1977 through 1997. The data come from the US Bureau of Economic Analysis. This dataset is separately analyzed for both industries and states. Using production function regressions and growth accounting techniques, the productive capacity and growth contribution of the IT capital stock is estimated at the state level. The results indicate a positive contribution to state productivity growth that amounts to 10% of the observed growth. Furthermore, decreasing returns to capital accumulation are found to apply to information technology capital, since its growth contribution is lower in states that own the highest shares of IT capital.*

Key-words - PRODUCTIVITY, REGIONAL ACTIVITY, INFORMATION TECHNOLOGY.

JEL Classification: 04, J24, R10, R11.

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1. INTRODUCTION

This paper analyzes the role of information technology in the economy of the United States, through its effects on regional labor productivity. The concept of information technology refers here to the convergence of computing power and communication technology that began in the late 1970s. This study was motivated by the debate over the so-called "productivity paradox," the oft-cited finding that investment in information technology appears to have had no visible effect on aggregate productivity. Indeed, until the mid-1990s, productivity gains remained sluggish while information technology was booming. Today, even after the recent jump in productivity, the strength of the "new economy" is once again called into question with the "deceleration" of growth and the apparent failure of the "e-economy."

Historical data (1977-1997) are re-examined in light of the redistribution hypothesis, which may deserve further investigation at the regional level. If information technology has a redistribution effect, then it "redistributes the shares of the pie without making it bigger," as stated by Brynjolfsson and Hitt (1993), who showed that IT capital does increase an individual firm's productivity. Thus, the slow diffusion of information technology across firms as well as across space may partly explain the productivity paradox.

The purpose of this paper is to further investigate the impact of the spatial diffusion of IT on the validity of the productivity paradox, by analyzing the productivity of IT at the regional level. Because information technology activity tends to be very localized (eight states own more than half of the entire national IT capital stock), there is reason to hypothesize *regional* redistribution effects regarding the impact of information technology. If this hypothesis is confirmed, then the productivity paradox is shown to have been a problem only at the aggregate level. This analysis focuses on information technology (hereafter IT) embodied in the stock of capital. A panel dataset is constructed for the 50 states plus the District of Columbia, covering 52 industry categories from 1977 through 1997. The data come from the US Bureau of Economic Analysis. This dataset is separately analyzed for both industries and states. Using production function regressions and growth accounting techniques, the productive capacity and growth contribution of the IT capital stock is estimated at the state level. The results indicate a positive contribution to state productivity growth that amounts to 10% of the observed growth. Furthermore, decreasing returns to capital accumulation are found to apply to information technology capital, since its growth contribution is lower in states that own the highest shares of IT capital.

2. LITERATURE REVIEW

During this last decade, many authors proposed explanations for the productivity paradox:

First, Ives (1994), Brynjolfsson and Hitt (1998) questioned the quality of measurement of national figures. Moving from a "hard" to a "soft" economy, with knowledge and information becoming primary resources, the productivity of difficult-to-measure intangibles has become more difficult to estimate. Second, David (1990) argued that long learning lags are associated with the diffusion of a new technology. The parallel was drawn from previous technological revolutions such as electricity or steam power, which had no significant impact on aggregate productivity figures until several decades after their discoveries. Roach (1998), Powell (2000) and Chapman (1996) proposed the "mismanagement" hypothesis, which stated that investors in information technology have underestimated its true cost (hidden costs include maintenance and training). A fourth hypothesis stated that unless IT investment is accompanied by work reorganization, productivity improvement will not occur (Brynjolfsson and Hitt, 1995; Bowen, 1986). Another explanation for the productivity paradox was the "redistribution" hypothesis, which proposed that IT is beneficial for individual firms, but not necessarily for the nation as a whole, as shown by Brynjolfsson and Hitt (1993), Jorgenson and Stiroh (1999, 2000). Finally, Oliner and Sichel (1994, 2000) argued that the income share of information technology capital is too small to have had visible macroeconomic effects, even if it does exhibit excess returns at the microeconomic level. Each hypothesis is a possibly valid explanation for the productivity paradox. However, today there seems to be a consensus around the idea that information technology finally started to increase productivity in the mid-1990s, as more and more firms completed the long reorganization of work process needed to accompany IT investment. As stated by Le Bas and Miribel (2005) agglomeration economies also played a more important role for IT activity than for traditional activity.

3. DESCRIPTIVE STATISTICS

States differ in their levels of output, capital and labor inputs. By the same token, they differ in their levels, shares and ratios of information technology. More than half of the total IT capital stock is located in only eight states: California, New York, Texas, Illinois, Florida, Pennsylvania, New Jersey and Ohio (Figure 3.1). California has the highest ranking by far, owning 13% of total IT capital stock of the United States in 1997, followed by New York with 9% and Texas with 8%. However, it is only the eighth most IT intensive state with an IT ratio of 9%, behind Washington DC (13%) and New York (11%). IT ratios vary between less than 4% and more than 13% as shown in Figure 3.2, but the dispersion is less important than the dispersion of their absolute and relative levels of IT capital.

Figure 3.1: Distribution of IT capital stock across the States in 1987

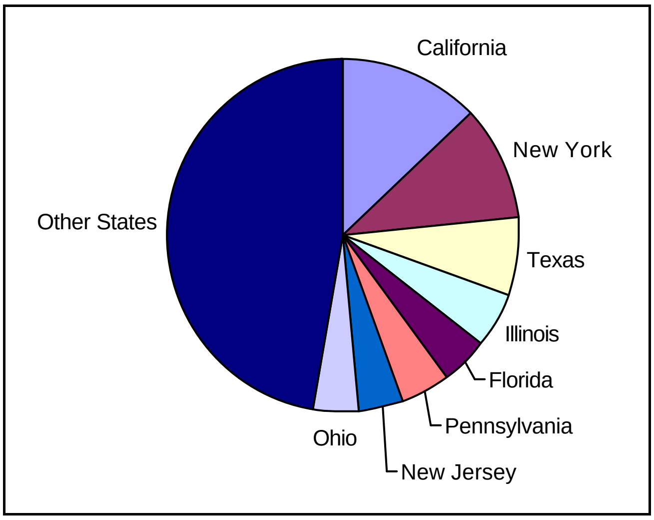
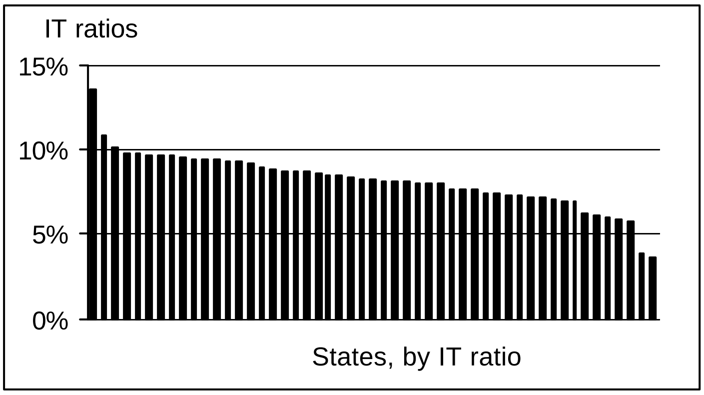


Figure 3.2: Ratios of IT capital stock to total capital (IT ratios) by State in 1987



4. THE MODEL

4.1. The excess returns hypothesis

The descriptive statistics presented earlier show that US states have invested heavily in IT equipment during the last two decades. At the origin of this massive investment was there certainly the premise that computer and information technology equipment in general could eventually increase firms' productivity, simply because this type of equipment was assumed to be more productive than traditional capital. This premise was empirically tested and authors reached different conclusions. On one hand, Berndt and Morrison (1995) argued that aggregate returns from IT investment were not significantly different from that of other types of capital. On the other hand, at the firm level, Brynjolfsson and Hitt (1993) estimated returns to IT investment between 50% and 60%. I intend to use a model derived from the work of Lehr and Lichtenberg (1999) to test whether returns from IT equipment are greater than that of traditional capital. This section describes this model.

To start with, assume that at time t, within state s, industry i transforms capital (K) and Labor (L) into output (Y) according to a constant returns to scale Cobb-Douglas production function and embodied technical progress:

$$Y_{its} = A\, K_{its}^{\alpha} L_{its}^{1-\alpha} \tag{4.1}$$

The parameter α represents the elasticity of output with respect to capital. Next, decompose total capital into information technologyy capital (KIT) and other types of capital aggregated into "traditional" or "non-IT" capital (KNIT). Thus

$$K_{its} = KNIT_{its} + KIT_{its} \tag{4.2}$$

Equation 4.1, given equation 4.2, now becomes

$$Y_{its} = A\left(KNIT_{its} + KIT_{its}\right)^{\alpha} L_{its}^{1-\alpha} \tag{4.3}$$

The neoclassical theory postulates that all types of capital earn the same marginal returns. This argument constitutes the null hypothesis that will be tested using this model. Under the alternative hypothesis, the return to IT capital differs from the return to traditional capital and is most likely greater. Let parameter θ capture the "excess productivity" from IT capital. Thus equation (4.3) becomes

$$Y_{its} = A\left[KNIT_{its} + (1+\theta)KIT_{its}\right]^{\alpha} L_{its}^{1-\alpha} \tag{4.4}$$

I will test the "excess returns" from IT capital hypothesis H1, which is derived next.

Replacing KNIT by K – KIT in equation 4.4 and dropping the subscripts for the sake of simplicity leads to

$$Y = A\left[K - KIT + (1+\theta)KIT\right]^{\alpha} L^{1-\alpha}$$

$$\Leftrightarrow \quad Y = A\left[K + \theta KIT\right]^{\alpha} L^{1-\alpha}$$

$$\Leftrightarrow \quad Y = A\left[K(1 + \theta KIT / K)\right]^{\alpha} L^{1-\alpha} \tag{4.5}$$

Taking logarithms, we can write

$$\Leftrightarrow \quad \ln(Y) = \ln(A) + \alpha \ln\left[K(1 + \theta KIT / K)\right] + (1 - \alpha)L \tag{4.6}$$

Finally, letting IT% represent the ratio of IT capital to total capital (KIT/K):

$$\ln(Y) = \ln(A) + \alpha \ln(K) + \alpha \ln[1 + \theta.IT\%] + (1 - \alpha)\ln(L) \qquad (4.7)$$

The null hypothesis states that all types of capital earn the same returns, net of depreciation and other costs associated with each type of capital asset. The first order condition for profit maximization requires that the ratio of the marginal products of IT capital to traditional capital be equal to the ratio of the user costs of these types of capital. This hypothesis refers to the equilibrium point A in Figure 3.1. If the ratio of returns were not equal to the ratio of user costs, then firms would be better off investing in the type of capital that had higher returns, and less on capital equipment with lower returns. Thus,

$$MP_{KIT} / MP_{KNIT} = R_{KIT} / R_{KNIT}$$
$$\Leftrightarrow \quad 1 + \theta = [(r + \delta_{KIT} - \pi_{KIT})p_{KIT}] / [(r + \delta_{KNIT} - \pi_{KNIT})p_{KNIT}] \qquad (4.8)$$

where MP is the marginal product, R is the user cost of capital, r measures the discount rate common to all types of capital, δ is the depreciation rate, π is the expected rate of capital gain (or loss in the case of IT capital), and p is the purchase price per unit of capital. Various authors have reported different estimates of user costs, mainly because they considered different values for r, δ and π. The ratio pKIT/pKNIT is set to unity because the two types of capital are measured in dollar values so that their prices are both $1. Table 4.1 reports various estimates of the elements of the user costs according to different authors' calculations. Averaging these estimates and replacing them in equation 4.8 leads to a value for the ratio of user costs of capital between 3 and 6, which is also equal to $1+\theta$. Lehr and Lichtenberg chose 5 as an upper bound estimate of θ. The null hypothesis of no excess returns then becomes a test of $\theta=5$. If θ is significantly greater than 5, then the null hypothesis is rejected and the alternative hypothesis of excess returns to IT capital cannot be rejected.

Interestingly, Lehr and Lichtenberg (1999) argued that as long as IT% is small (in the order of 2%), it is possible to substitute $\alpha\theta$(IT%) for $\alpha\ln(1+\theta IT\%)$.[1] Consequently, equation 4.7 becomes:

$$\ln(Y) = \ln(A) + \alpha \ln(K) + \alpha\theta IT\% + (1 - \alpha)\ln(L) \qquad (4.9)$$

From equation 4.1, the growth in productivity not explained by inputs or total factor productivity (TFP) is

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[1] The validity of this substitution was tested using a set of values between 1% and 15% for IT% (values found in the dataset between 1977 and 1997), and between 4 and 10 for θ. A linear regression of [α ln (1+θIT%)] on [$\alpha\theta$IT%], with no constant, produces a coefficient for [$\alpha\theta$IT%] not statistically different from 1 at the 0.01 level.

$$TFP = A = Y / \left(K^{\alpha} L^{1-\alpha}\right) \quad (4.10)$$

Taking logarithms and replacing TFP in equation 4.9 leads to

$$\ln(TFP) = \ln(A) + \alpha\theta IT\% \quad (4.11)$$

Also, dividing both sides of equation 4.5 by L and taking logarithms

$$\ln(Y/L) = \ln(A) + \alpha \ln(K/L) + \alpha\theta IT\% \quad (4.12)$$

Table 4.1: Values of discount rate, depreciation and price appreciation estimated from various sources

Variable	*Source*	*Estimates*	*Mean*
Risk-adjusted discount rate (r)	Lau and Tokutsu (1992) Oliner and Sichel (1994)	0.07 0.12	0.10
IT capital Depreciation rate (δ_{KIT})	Kiley (1999) Lau and Tokutsu (1992) Whelan (1999) Oliner and Sichel (2000)	0.12 0.20 0.22 0.30	0.21
Non-IT capital Depreciation rate (δ_{KNIT})	Whelan (1999) Lau and Tokutsu (1992)	0.13 0.05	0.09
Rate of price depreciation for IT capital (π_{KIT})	Lau and Tokutsu (1992) Kiley (1999) Oliner and Sichel (2000)	-0.15 -0.24 -0.34	-0.24
Rate of price appreciation for non-IT capital (π_{KNIT})	Lau and Tokutsu (1992)	0.05	0.05

Under the null hypothesis of no excess returns to IT capital, the share of IT capital (IT% or IT ratio) will not increase TFP and labor productivity according to equations 4.11 and 4.12, respectively ($\alpha\theta = 0$). However, if the null hypothesis is rejected, then TFP and labor productivity might increase with the share of IT capital ($\alpha\theta > 0$).

In this study, I use a pooled cross-section dataset on industry variables at the state level between 1977 and 1997. Econometric analysis of pooled data requires the introduction of fixed effects or dummy variables for years, industries and states. These fixed effects will control for exogenous differences among years (γt), industries (λi), and states (νs). The first Cobb-Douglas production function that will be estimated at the national, industry and state levels is

$$Y_{its} = A\, KNIT_{its}^{\alpha 0}\, KIT_{its}^{\alpha 1}\, L_{its}^{\beta} \quad (4.13)$$

Taking logarithms and introducing dummy variables to control for fixed effects, the least squares dummy variables (LSDV) functional form is:

$$\ln(Y_{its}) = \Sigma\gamma_{t-1} + \Sigma\lambda_{i-1} + \Sigma\nu_{s-1} + \alpha_0 \ln(KNIT_{its}) + \alpha_1 \ln(KIT_{its}) + \beta \ln(L_{its}) + \varepsilon_{its} \quad (4.14)$$

A simple test of whether IT capital is productive is to test the null hypothesis H0: $\alpha 1 > 0$. Then, equation 4.9 needs to be estimated. Its econometric form is:

$$\ln(Y_{its}) = \gamma_{t-1} + \lambda_1 + \nu_s + \alpha \ln(K_{its}) + \alpha \theta (IT\%)_{its} + (1-\alpha)\ln(L_{its}) + \varepsilon_{its} \quad (4.15)$$

where α_0 and α_1 measure the output elasticities of traditional and IT capital respectively. If θ is significantly greater than 5 then the hypothesis H0 of similar returns for IT and traditional capital would be rejected.

4.2. Contribution to output and productivity growth

After testing for the sign and significance of the output elasticity of IT capital, I will measure the contribution of this type of capital to output and productivity growth. Considering equation 4.14 in growth rates leads to

$$gr(Y_{its}) = \gamma_{t-1} + \lambda_i + \nu_s + s_{KNIT} gr(KNIT_{its}) + s_{KIT} gr(KIT_{its}) + s_L gr(L_{its}) + \mu_{its} \quad (4.16)$$

The contribution to output growth from IT capital is measured by $s_{KIT}gr(KIT_{its})$ where gr stands for "growth rate" measured as the ratio of the difference between variables at time t and t-1, divided by the value at time t-1. Many authors use first log differences to measure growth rates, but I believe the previous formula is more accurate.[2] Variable s represents the income share of inputs (previously defined by equation 3.5), and in equilibrium it is equal to the input's marginal product times its share of output. Finally, μ represents the error term.

Following Oliner and Sichel (2000), equation 4.16 is divided on both sides by Lits to estimate the labor productivity growth contribution of a given input. The authors also control for labor quality by adding variable gr(q), where q could represent years of experience or education:

$$gr(Y_{its}/L_{its}) = \gamma_{t-1} + \lambda_i + \nu_s + \alpha_0 gr(KNIT_{its}/L_{its}) + \alpha_1 gr(KIT_{its}/L_{its}) + \alpha_L gr(q) + \mu_{its} \quad (4.17)$$

Thus, growth in labor productivity depends on growth in TFP (which is captured by various fixed effects ($\gamma_{t-1} + \lambda_i + \nu_s$), capital deepening (growth in KNIT/L and KIT/L) and change in labor quality gr(q).

[2] I use $(Z_t - Z_{t-1}) / Z_{t-1}$. Note that $\ln [(Z_t - Z_{t-1}) / Z_{t-1}] = \ln (Z_t - Z_{t-1}) - \ln (Z_{t-1})$, which is different from $\ln (Z_t) - \ln (Z_{t-1})$.

Table 4.2: Variable definitions and sources

Variable	*Name*	*Definition*	*Data*
T	Time	Year indices	t = 1…21 for years = 1977-1997
I	Industry	Industry indices	i = 1…52 for 2-digit SIC = 31-5310
S	State	State indices	s = 1…51 for fips = 01-56
Y	Output	Aggregate Value-added	"Gross Product Originating" BEA
K	Total Capital	Capital Stock, measured as the net wealth stock of nonresidential equipment and structure	"Fixed Reproducible Tangible Wealth" BEA
KIT	Information technology capital	IT capital stock, measured as the stock of Information Processing Equipment	"Fixed Reproducible Tangible Wealth" BEA
KNIT	Traditional or non-IT capital	Capital stock other than Information Processing Equipment	KNIT = K – KIT
IT%	IT ratio	Share of IT capital in total capital	ITP = KIT/K
E	Employment	Number of full-time equivalent employees	GPO from BEA
H	Hours	Average yearly hours (52* average weekly hours)	Bureau of Labor Statistics
L	Labor hours	Total number of hours worked	L = E * H

For more information on data and variables see Miribel (2001).

4.3. Variables and data

The main variables of the model previously described are output (Y), traditional and IT capital (KNIT and KIT respectively) and labor (L). Different levels of study (national, industries and states) make the construction of the dataset complex.

In this study, I consider pooled cross-section data for 52 industries, for 50 contiguous US states and the District of Columbia, for the 21 years between 1977 and 1997 inclusive. The industries account for all of the nonagricultural nongovernmental production in the US economy.

5. RESULTS

This part describes the empirical results from the analysis presented earlier. The sections 5.1 and 5.2 report evidence on the returns to IT capital stock and the "excess" return hypothesis, respectively. Then, in section 5.3, the contribution to output growth of IT capital is estimated for each state between 1977 and 1997. Section 5.4 describes the results regarding the labor productivity growth contribution of IT capital, by state. Finally, section 5.5 summarizes findings and draws the comparison with other studies.

5.1. Is IT capital a productive input?

In this section, I present the empirical results related to the measurement of the productive capacity of IT capital. Derived from equations 4.14 and 4.13, the two following equations are estimated:

$$\ln(Y)_{its} = \ln(A) + \alpha_1 \ln(KIT)_{its} + \alpha_2 \ln(KNIT)_{its} + \beta \ln(L)_{its} \qquad (5.1)$$

Using fixed effects for industries, states and years

$$\begin{aligned} \ln(Y)_{its} &= \ln(A) + \Sigma_{i-1}Di + \Sigma_{s-1}Ds + \Sigma_{t-1}Dt \\ &\quad + \alpha_1 \ln(KIT_{its}) + \alpha_2 \ln(KNIT)_{its} \beta \ln(L)_{its} \end{aligned} \qquad (5.2)$$

Coefficients α_1, α_2, and β represent the output elasticities to various inputs, which are also the percent change in output for a 1% change in the quantity of input. An input is a productive resource if its output elasticity is significantly positive. These parameters can also be considered as the marginal products of each input, which represent the amount of additional output provided for an additional dollar invested in the input. Table 5.1 reports estimates of elasticities for equation 5.1. Results indicate a positive and significant elasticity (or marginal product) of IT capital input at all levels of study (with a value between 0.115 and 0.211), except for the estimation of equation 5.2 at the level of detailed industries nationally.

Table 5.1: Estimates of elasticities for equations 5.1 and 5.2 for detailed industries by state, for aggregated industries by state and for detailed industries at the national level

Equation Estimated	*(5.1)*	*(5.2)*	*(5.1)*	*(5.2)*	*(5.1)*	*(5.2)*
Level of study	Detailed	Detailed	Aggre-	Aggre-	Detailed	Detailed
Fixed Effects	No	Yes:	No	Yes:	No	Yes:
Constant	2.936	1.470	2.684	3.414	4.298	14.591
IT capital	0.196	0.021	0.211	0.092	0.210	(-0.007)
Non-IT capital	0.162	0.337	0.125	0.216	0.130	(-0.000)
Labor	0.638	0.632	0.671	0.650	0.597	0.386
R^2	0.95	-	0.99	-	0.95	0.98
Durbin Watson	1.83	-	1.56	-	-	-
Time periods	21	21	21	21	21	21
Industries	52	52	-	-	52	52
States	51	51	51	51	-	-
N	55,692	55,692	1,071	1,071	1,092	1,092

Note: All coefficients are significant at the 0.01 level, except those in parentheses.

First, equations 5.1 and 5.2 were estimated at the detailed industries level, by state and year, representing 55,692 observations (one observation for each industry, in each state, for each year). Without the use of fixed effects (equation 5.1), results indicate output elasticities of 0.196 for IT capital, 0.162 for traditional capital, and 0.638 for hours worked. These coefficients are close to their expected values in the presence of constant returns to scale (0.66 for labor and 0.33 for total capital). The R-squared and Durbin Watson (0.95 and 1.83, respectively) indicate a high degree of explanatory power of the model and the absence of serial correlation in the error term. However, the elasticity of IT capital drops from 0.196 to 0.021 when industry, state and time fixed effects are accounted for (equation 5.2). This result indicates that roughly 90% of the elasticity of IT capital may be attributable to industry, state and time effects. Thus, there are industry and state differences, across years, regarding the productive capacity of IT capital, and these differences may increase the estimates of the marginal product of IT capital by 90%. Still, this elasticity is significantly positive, and IT capital can be considered as a productive input.

Equation 5.1 is also estimated at the state level (aggregated industries, by state and by year). Results are similar, but vary when fixed state and time effects are introduced (equation 5.2). The estimated elasticity drops from 0.211 to 0.092 because of state and time effects. Equation 5.1 is finally estimated at the detailed industries national level. Results show that the output elasticities are similar to the ones at the detailed industries level by state. However, regression using fixed effects (equation 5.2) produces estimates of output elasticities of capital not significantly different from zero.

Table 5.2: Estimates of elasticities from equation 5.2 for selected industry sectors across states

Sector	*Constant*	*IT capital*	*Non-IT capital*	*Labor*
All[3]	3.719	0.247	0.126	0.600
Manufacturing:	4.209	0.191	0.247	0.470
Durable goods	3.149	0.113	0.194	0.664
Nondurable Goods	5.333	0.317	0.124	0.435
Service Sector:	3.301	0.219	0.127	0.657
Transportation	3.120	0.213	0.250	0.500
Trade[4]	1.944	0.016	0.920	(-0.01)
FIRE[5]	5.069	-0.556	0.970	0.335
Service Industry	4.210	0.171	-0.030	0.835

*Note: Separate regressions for each sector, with time and state dummies. All coefficients are significant at the 0.01 level, except those in parentheses. The number of observation for each regression is 1,071 (1 observation for each state, each year: 51*21 = 1,071).*

To understand better how input elasticity estimates vary at the different levels of analysis, I estimated equations 5.1 (or 5.2 when fixed effects were needed) by selected industry sector, by year and by state. Results appear in Tables 5.2, 5.3 and 5.4, respectively.

[3] Except mining and construction sectors, for which the estimated coefficients are insignificant.

[4] Wholesale and Retail trade.

[5] Finance, Insurance and Real Estate sector, Except "holding and investment" industry because of data concerns.

Results of regression 5.2 vary across industry sectors as reported in Table 5.2. The output elasticity of IT capital is positive and significant for all sectors except Finance, Insurance and Real Estate (FIRE). This is probably due to mismeasurement errors resulting from the difficulty of measuring inputs and outputs in this sector.

For all sectors aggregated, the output elasticity of IT capital is 0.247, and it is greater than the output elasticity of traditional capital (0.126). The sum of output elasticities is not significantly different from one for all regressions, which support the constant returns to scale hypothesis. The service sector has a greater output elasticity of IT capital than the manufacturing sector (0.219 and 0.191 respectively), but the difference is small. The nondurable goods manufacturing sector has the highest elasticity of IT capital (0.317). IT capital has a greater output elasticity than traditional capital in the service sector, while the reverse is true in the manufacturing sector. The coefficients for Finance, Insurance and Real Estate (FIRE) sector is negative for IT capital. Once again, this may be due to the difficulty of measuring output in that industry (mismeasurement hypothesis).

The output elasticities of inputs vary also across time during the last two decades. Table 5.3 reports estimates of equation 5.1 for each year between 1977 and 1997. These output elasticities are all positive and significant. The aggregate output elasticity of IT capital ranges from 0.13 in 1977 to more than 0.27 in 1982. Figure 5.1 clearly shows the gap between output elasticities of IT capital and traditional capital. The difference between the output elasticities of the two types of capital was highest during the 1980s.

Table 5.3: Estimates of equation 5.1 over time

Year	*Constant*	*IT capital*	*Non-IT capital*	*Labor*
1977	3.13	0.13	0.21	0.65
1978	3.26	0.17	0.15	0.67
1979	3.36	0.21	0.12	0.65
1980	3.28	0.24	0.07	0.68
1981	3.25	0.26	0.07	0.67
1982	3.28	0.27	0.05	0.67
1983	3.17	0.27	0.07	0.66
1984	3.06	0.25	0.09	0.66
1985	3.06	0.25	0.10	0.65
1986	3.02	0.23	0.12	0.64
1987	3.08	0.24	0.13	0.62
1988	3.00	0.23	0.15	0.62
1989	3.06	0.24	0.13	0.63
1990	2.97	0.23	0.13	0.63
1991	2.79	0.22	0.17	0.62
1992	2.73	0.21	0.17	0.62
1993	2.78	0.22	0.17	0.61
1994	2.78	0.22	0.18	0.60
1995	2.83	0.23	0.18	0.59
1996	2.77	0.24	0.19	0.56
1997	2.83	0.25	0.19	0.55

Note: No fixed effects included. All coefficients significant at the 0.01 level.

Table 5.4 presents elasticities estimates from equation 5.2 for each of the 51 states at two levels: (1) at the detailed industries level (controlling for industry fixed effects) and (2) at the aggregated industry level. At the detailed industries level, all coefficients are significant and the output elasticity of IT capital (α_1) averages 8.48% across states, with a standard deviation of 1.22.

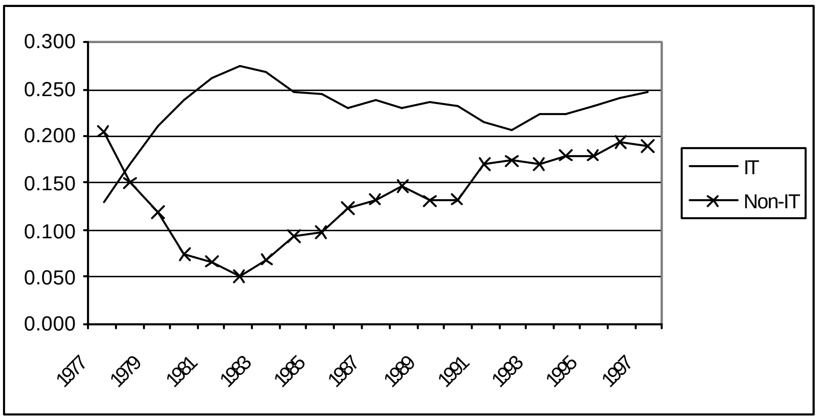
Table 5.4: Estimates of elasticities from equation 5.1 for detailed and aggregated industries by state

Level of Analysis	Detailed Industries				Aggregated Industries			
State	Constant	IT capital	Non-IT capital	Labor	Constant	IT capital	Non-IT capital	Labor
Alabama	2.61	9.2	27.6	55.2	(-3.96)	(11)	(21)	98
Alaska	0.68	7.9	36.0	60.0	9.88	17	14	33
Arizona	3.06	11.0	33.6	45.6	2.31	21	(9)	72
Arkansas	4.95	10.2	23.6	42.4	(-0.27)	11	20	81
California	2.17	8.6	28.0	60.2	(-0.71)	13	30	68
Colorado	3.86	10.5	30.7	43.7	6.44	20	(-5)	70
Connecticut	4.02	8.7	15.4	61.6	(-0.77)	13	31	69
Delaware	2.11	7.8	28.3	61.3	-7.90	(-6)	77	73
Dist. Of Col.	2.18	6.3	29.9	59.6	1.62	8	19	78
Florida	3.02	8.9	22.8	60.7	1.58	9	24	70
Georgia	3.13	8.6	21.7	57.0	-5.40	(2)	44	82
Hawaii	3.08	6.5	21.3	71.6	1.86	7	15	82
Idaho	2.09	9.1	30.9	56.2	3.42	21	(-199)	88
Illinois	4.69	8.3	19.0	51.7	-6.06	14	57	60
Indiana	3.10	7.6	27.9	59.9	-7.69	8	57	75
Iowa	5.16	8.1	29.5	47.5	(-0.14)	15	34	61
Kansas	4.05	8.2	32.5	48.3	13.90	19	(-11)	42
Kentucky	4.23	8.3	24.0	58.4	9.76	18	-57	1.19
Louisiana	1.61	8.0	33.6	57.2	11.62	16	(-6)	52
Maine	4.23	9.9	20.9	49.4	-7.62	(5)	53	87
Maryland	3.04	8.9	30.5	50.7	-1.84	9	46	61
Massachusetts	2.65	7.9	25.3	57.7	-1.55	13	42	60
Michigan	3.78	8.9	25.8	52.7	-8.31	7	66	68
Minnesota	4.72	9.6	24.7	48.5	(2.27)	18	(-5)	92
Mississippi	3.93	7.4	26.2	58.2	(-0.45)	15	20	79
Missouri	4.54	9.2	27.7	44.0	-8.50	(2)	71	69
Montana	1.86	9.2	37.2	49.1	10.34	20	-26	76
Nebraska	2.32	6.9	30.5	58.7	(-0.31)	10	29	73
Nevada	2.59	9.7	31.7	51.9	(0.28)	(-1)	15	97
New Hampshire	2.64	7.3	28.7	63.3	(0.21)	20	18	73
New Jersey	3.05	7.5	20.6	62.9	-4.01	10	18	66
New Mexico	1.91	9.7	37.6	47.8	7.55	20	-45	1.13
New York	6.74	6.6	10.3	52.5	(0.85)	20	16	71
North Carolina	2.36	6.7	21.9	71.0	6.91	20	-61	1.34
North Dakota	2.62	7.8	36.1	52.4	6.88	13	-4	37
Ohio	3.78	8.2	23.5	48.1	(-0.70)	20	(12)	82
Oklahoma	4.12	9.1	28.0	41.9	11.70	16	-10	55
Oregon	2.36	9.3	33.0	49.5	1.68)	19	(1)	87
Pennsylvania	2.94	7.4	23.5	58.5	(-0.47)	18	40	51
Rhode Island	4.49	7.2	17.8	66.5	-7.38	6	47	92
South Carolina	1.49	5.7	26.6	72.2	-3.95	15	27	86
South Dakota	1.67	8.2	31.7	58.7	4.76	14	21	53
Tennessee	5.21	11.4	16.6	51.6	-4.04	7	41	79
Texas	1.74	8.7	32.1	57.1	16.45	37	-44	56
Utah	1.96	9.7	37.4	47.9	11.27	33	-43	79
Vermont	4.92	8.9	20.9	58.9	(0.44)	14	26	69
Virginia	3.09	9.7	27.5	50.7	5.34	14	(-2)	79
Washington	2.07	10.1	37.0	46.7	2.09	11	42	45
West Virginia	4.22	6.9	21.1	55.0	12.93	41	-55	76
Wisconsin	3.09	8.8	27.6	52.4	(2.82)	20	(-8)	91
Wyoming	2.33	8.5	38.9	43.9	21.35	44	-79	60

*Note: Elasticities are expressed in percentage. All coefficients are significant at the 0.01 level except those in parentheses. For detailed industries regressions (using industry dummy variables), there are 52 industries * 21 years = 1,092 observations for each state. For aggregated industry there are 21 observations for each state.*

Tennessee and Arizona present the highest returns to IT capital stock (greater than 11%), and South Carolina and Hawaii the lowest. This means that some states seem to use IT capital more efficiently than others, even though the differences do not seem to be very important. Eight of the "most IT" states (Figure 3.1) present an output elasticity of IT capital less than or equal to the overall states' average of 8.48%. Hence, the returns to IT capital do not seem to be the greatest for states that own the highest share of IT capital. At the aggregated industry level by state, many coefficients are not significant, and regression results vary significantly from the results at the detailed industries level. This is certainly due to the fact that, at the aggregated industry level, only 21 observations are available for each state (one for each year), as opposed to 1,092 observations per state at the detailed industries level (one for each industry each year). The average output elasticity of IT capital at the aggregated industries level is higher than at the detailed industries level (14.82% and 8.48%, respectively), and the standard deviation is 10 times greater. Furthermore, at this aggregated industries level, output elasticities of IT capital for the most IT states are greater than or equal to average elasticity, except for California, which owns the highest share of the nation's IT capital stock.

Figure 5.1: Trends in aggregate output elasticities of it and traditional capital, 1977-1997



Hence, several conclusions can be drawn from the estimates of equations 5.1 and 5.2. First of all, IT capital is a productive input, that has an output elasticity estimated at roughly 0.20 at the detailed industry level by state, but industry and state fixed effects may account for most of this value. At the sectoral level, there are no major differences between manufacturing and the service sector regarding output elasticities of IT capital (also estimated at around 0.20), but there are some differences at a more disaggregated level. Indeed, the elasticity IT capital is highest for the nondurable goods sector (0.32) and lowest for the trade sector (0.02), not including the negative elasticity for the F.I.R.E. sector, which may be due to measurement difficulties in that sector. The returns to IT capital are relatively stable at the national level over time (between 0.15 and 0.25), with an increase until 1983, a plateau for the rest of the 1980s, and a slight increase since the early 1990s. Finally, the average returns to IT capital across states is around 0.08 at the detailed industries level across states, and is around 0.14 at the aggregated industries level across states. However, results from the aggregated industries level must be interpreted carefully since only 21 observations were available for each state. From the detailed industries regression results, the returns to IT capital appear lower than average in states that own the highest share of the nation's IT capital stock.

Hence, based on all these findings, IT capital stock seems to be a productive input with an output elasticity that varies between 10% and 20%, and between 2% and 10% when fixed effects are introduced. In order to further investigate the productive capacity of IT capital, the next section discusses the "excess" returns hypothesis.

5.2. Excess returns from IT capital

In this section I present some evidence on the "excess" return hypothesis, which states that returns to IT capital are greater than those to traditional capital. In order to test this hypothesis, I estimated the following equation (based on equation 4.9 and 4.15, respectively):

$$\ln(Y)_{its} = \ln(A) + \alpha \ln(K)_{its} + \alpha\theta(IT\%)_{its} + (1-\alpha)\ln(L)_{its} + \varepsilon_{its} \quad (5.3)$$

Introducing fixed effects and taking logarithms:

$$\ln(Y)_{its} = \ln(A) + \Sigma\gamma_{t-1} + \Sigma\lambda_i + \Sigma\nu_s + \alpha\ln(K)_{its} + \alpha\theta(IT\%)_{its} + (1-\alpha)\ln(L)_{its} + \varepsilon_{its} \quad (5.4)$$

Table 5.5 reports estimates of equations 5.3 and 5.4. The coefficients for capital and labor reach their expected constant return to scale values of 1/3 and 2/3 respectively. When no fixed effects are accounted for, θ has a value significantly greater than 5 (7.54), which leads to the conclusion that IT capital exhibits excess returns over traditional capital. Regressions with fixed industry effects show a value of $\theta = 9$, also significantly higher than 5, which means that IT capital has a return higher than that of traditional equipment. Finally, regression results at the state level also indicate excess returns to IT capital ($\theta = 7.91$), but not when state and time effects are introduced. Thus, the excess returns of IT capital may be partly due to differences across states and time.

Equation 5.3 is then estimated for selected sectors, years and states. Results appear in Tables 5.6, 5.7 and 5.8, respectively. Table 5.6 shows that, except for FIRE and transportation industries, the value of θ is significantly greater than 5, which confirms the hypothesis of excess returns to IT capital. The highest value was found in the service industry ($\theta = 22.2$). Equation 5.3

is also estimated for each year between 1977 and 1997. Results appear in Table 5.7. First, the coefficients for capital increased over time (from 0.271 to 0.433), and the coefficient for labor decreased (from 0.693 to 0.535), but these coefficients remained close to their expected values of 0.33 and 0.66, respectively.

The increase in the coefficient for capital is probably mostly due to the increase in the returns to IT capital over time. Between 1980 and 1993, the estimated value of θ is significantly greater than 5, indicating excess returns to IT capital for these years.

Table 5.5: Estimates of elasticities for equations 5.3 and 5.4 for detailed industries by state, for aggregated industries by state and for detailed industries at the national level

Regression	(5.3)	(5.4)	(5.3)	(5.4)	(5.3)	(5.4)
Level of study	Detailed industries by state	Detailed industries by state	Aggregated industries by state	Aggregated industries by state	Detailed industries at the national level	Detailed industries at the national level
Fixed effects	No	Yes: Di, Ds, Dt	No	Yes: Dt, Ds	No	Yes: Di
Constant	2.126	1.350	2.004	3.614	3.010	11.44
Capital	0.336	0.345	0.314	0.270	0.321	0.219
IT Ratio	2.533	-1.129	2.483	(0.131)	2.634	1.974
Labor	0.663	0.645	0.694	0.671	0.639	0.276
R^2	0.945	-	-	-	0.803	0.976
θ	7.54	-3.27	7.91	(0.48)	8.20	9.01
Time periods	21	21	21	21	21	21
Industries	52	52	-	-	52	52
States	51	51	51	51	-	-
N	55,692	55,692	1,071	1,071	1,092	1,092

Table 5.6: Estimates of elasticities from equation 5.4 for selected industry sectors across states

Sector	*Constant*	*Capital*	*IT Ratio*	*Labor*	*q*
All[6]	2.461	0.347	2.517	0.633	7.3
Manufacturing:	3.269	0.446	3.908	0.457	8.8
Durable goods	2.867	0.282	3.810	0.673	13.5
Nondurable Goods	3.494	0.479	4.557	0.405	9.5
Service Sector:	2.325	0.306	1.933	0.701	6.3
Transportation	1.993	0.414	1.866	0.553	4.5
Trade[7]	3.167	0.611	0.584	0.297	1.0
FIRE[8]	1.187	0.306	-6.331	0.826	-20.7
Service Industry	3.468	0.105	2.329	0.871	22.2

Figure 5.2 represents the evolution of θ over the period 1977-1997. The first and last three years of the period do not seem to exhibit excess returns to IT capital because of a low value of θ. This is explainable by the heavy fixed

6 Except mining and construction sectors, which yield insignificant estimates.
7 Wholesale and Retail trade.
8 Finance, Insurance and Real Estate, except "holding and investment" industry.

costs associated with the introduction of IT capital in the economy in the late 1970s, preventing excess returns. Finally, in the early 1990s the excess returns capacity of IT capital may have been exhausted after its important price (and marginal return) declined.

Equations 5.3 and 5.4 are finally estimated for each state at the detailed and aggregated industries levels, by state. However, the elasticities estimates do not indicate excess returns to IT capital for any of the states, with a value for θ not significantly different or even lower than 5. Therefore, IT capital does seem to exhibit excess returns at the national aggregated level and at the sectoral level, but not at the state level.

Figure 5.2: Trend in parameter *q*, ***1977-1997***

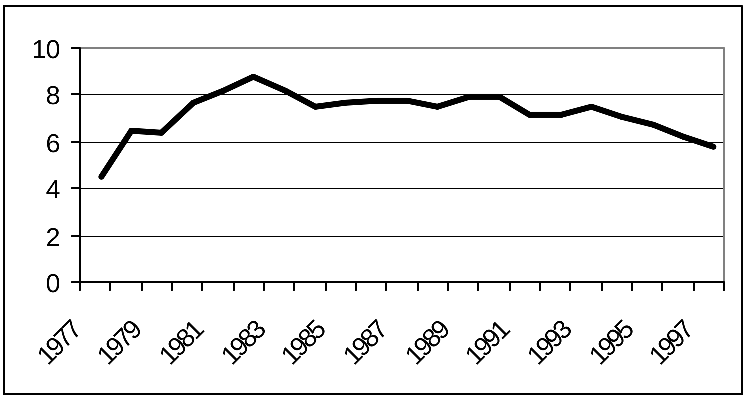


Table 5.7: Estimates of elasticities from equation 5.4 over time

Year	*Constant*	*Capital*	*IT Ratio*	*Labor Hours*	*q*
1977	2.550	0.271	1.079	0.693	4.0
1978	2.516	0.253	1.505	0.720	6.0
1979	2.354	0.274	1.616	0.693	5.9
1980	2.211	0.263	1.891	0.717	7.2
1981	2.079	0.281	2.172	0.698	7.7
1982	2.107	0.281	2.331	0.694	8.3
1983	1.980	0.299	2.304	0.682	7.7
1984	2.027	0.307	2.164	0.678	7.0
1985	2.087	0.315	2.257	0.667	7.2
1986	2.300	0.317	2.297	0.663	7.3
1987	2.295	0.341	2.476	0.632	7.3
1988	2.246	0.351	2.454	0.629	7.0
1989	2.291	0.344	2.546	0.632	7.4
1990	2.231	0.340	2.523	0.641	7.4
1991	2.168	0.360	2.395	0.628	6.7
1992	2.149	0.358	2.380	0.636	6.7
1993	2.205	0.369	2.589	0.620	7.0
1994	2.230	0.383	2.507	0.603	6.6
1995	2.263	0.399	2.475	0.580	6.2
1996	2.249	0.424	2.444	0.549	5.8
1997	2.315	0.433	2.307	0.535	5.3

5.3. Output growth contribution of it capital, by state

This analysis is concerned with the *relative* contributions of IT to output growth among states, and not their *absolute* levels. IT capital might have a low *absolute* contribution, and still a high contribution *relative* to a state's share of national IT stock. The idea is that many states have seen positive effects of IT on productivity but these states account for a small share of the national IT capital stock. Only 10% of the states own more than 50% of the total US stock of IT capital. Hence, aggregating the states' contributions may show a small overall contribution of IT to productivity in the United States. Indeed, as stated ealier, more than 50% of the US total IT capital stock is located in 8 states: California, New York, Texas, Illinois, Florida, Pennsylvania, New Jersey and Ohio. More than 80% of this stock is located mainly in the service sector (and more specifically in transportation, FIRE, services and retail trade, respectively) and manufacturing accounts for 15%. Thus, the question of IT and productivity should be analyzed with a closer look at what happened in these eight states and specifically in their transportation, FIRE, services, manufacturing and wholesale trade industries.

Following the method of Oliner and Sichel (1994), I assume the output growth contribution of IT capital (OGC_{KIT}) can be computed as the product of IT capital's income share and its growth rate. The income share is defined as the product of the return to IT capital (r) times the ratio of its stock with total output (KIT/Y):

$$OGC_{KIT,t} = \left[r * (KIT / Y)_{t-1}\right] * gr(KIT)_t \qquad (5.5)$$

where *t* denotes the year and *r* is the return to IT capital net of depreciation. I computed the average yearly output growth contribution for each state. Results appear in Table 5.8. States are sorted in descending order by their respective growth contribution. This contribution is also expressed as a percentage of a state's output growth rate. The average growth rates of output and IT capital stock are also given for each state. The average share of a state IT capital stock over the total national stock and the state IT ratio also appear in Table 5.8. According to these results, the contribution of IT capital to output growth ranges from less than 5 to more than 14 average yearly percentage points.

Oliner and Sichel (1994) found a comparable average contribution of 16 percentage points for the period 1970-1992 at the national level. However, this absolute value depends on the methodology adopted, which varies greatly among authors. Here, the focus is on the relative contribution by state. The main result is that there are some important variations in the output growth contribution of IT capital among states. Furthermore, according to the theory of convergence, as capital accumulates, the speed of convergence is reduced. In other words, it is possible that the output growth contribution of IT capital is lower in states that own a larger share of the national IT capital stock. As stated earlier, eight states own more than half of the IT capital stock of the

United States. If output growth contributions are lower in these states, the overall national aggregated contribution of IT capital to output growth would also be lower. This would also partly explain the productivity paradox. Looking at Table 5.8, it seems that these eight states do not indeed present the highest growth contribution of IT capital: California, New York, Texas, Illinois, Florida, Pennsylvania, New Jersey and Ohio are ranked 26th, 49th, 9th, 32nd, 11th, 44th, 28th and 41st, respectively.

The average ranking for those eight states is 30th. Although not significant, the correlation between the contribution to growth and the share of national IT capital stock is estimated at -0.07. Hence, IT capital may make an important contribution to growth for many states and a less important one in the few states that account for most of the national IT capital stock. Thus, the productivity paradox may be true at the national level, not at the level of individual states.

5.4. Labor productivity growth contribution of IT capital, by state

This section focuses on the contribution of IT capital stock to growth in labor productivity by sate. The equation estimated is:

$$gr\left(Y_s / L_s\right) = \alpha_0 gr\left(KNIT_s / L_s\right) + \alpha_1 gr\left(KIT_s / L_s\right) + TFP \qquad (5.6)$$

Labor productivity growth depends on IT and traditional capital deepening (KIT/L and KNIT/L), and total factor productivity (TFP), which includes labor quality in this study. First, output, capital and hours worked are aggregated across industries for each state each year between 1977 and 1997. In order to compute income shares for each state and years, the lagged ratio of input to output must be multiplied by the input's marginal return. Average output elasticities, or marginal returns of IT and traditional capital, are estimated from equation 5.2 for each state at the detailed industry level (Table 5.4). Income shares are computed for each state each year. Growth rates of IT and traditional capital per hour worked (capital deepening) are computed for each state each year. All these values are averaged over the period 1977-1997. Then, the labor productivity growth contribution of IT and traditional capital deepening are computed by state, as the product of average income shares and average growth rates. Table 5.9 shows: the productivity growth contribution and percentage of average growth in state productivity for IT and traditional capital; the average growth rate of state productivity; IT and traditional capital deepening; and TFP, respectively. Across states, 6% of the average labor productivity growth was due to IT capital deepening, 18% was due to other non-residential capital deepening, and the remaining 76% was due to residential capital deepening, labor quality improvement and total factor productivity. However, these results vary by state. The contribution of IT capital deepening varies from 2.25% to 11.07% across states. Furthermore, some of the lowest contributions of IT capital deepening are observed in the states that own more than half of the country's IT capital stock. Indeed, California, New York, Texas, Illinois, Florida, Pennsylvania, New Jersey and

Table 5.8: Contribution of IT capital to output growth, by state, 1977-1997

Rank	State	Output growth contribution of IT	Percentage of output growth due to IT	Output growth	Growth of IT capital	Share of national IT capital stock	IT ratio
1	Colorado	14.16	3.38	4.19	10.91	1.59	10.02
2	Arizona	13.06	2.28	5.72	11.41	1.18	8.38
3	Georgia	11.76	2.42	4.85	11.68	2.66	9.61
4	Delaware	11.20	2.71	4.13	11.41	0.43	9.83
5	New Mexico	11.20	2.71	4.13	10.58	0.49	6.31
6	Washington	11.18	3.01	3.72	10.43	1.86	9.51
7	Utah	11.07	2.41	4.60	10.73	0.54	7.27
8	Virginia	10.92	3.29	3.32	10.57	2.37	9.41
9	Texas	10.69	2.89	3.70	10.74	7.63	7.41
10	Tennessee	10.38	2.83	3.66	9.14	1.59	8.90
11	Florida	10.09	2.19	4.61	10.01	4.45	9.79
12	Nevada	9.94	1.68	5.91	10.94	0.47	6.04
13	Arkansas	9.75	3.22	3.03	9.01	0.68	7.60
14	Minnesota	9.58	2.82	3.39	10.07	1.65	8.31
15	Oregon	9.55	2.47	3.87	10.26	0.97	8.67
16	Missouri	9.53	3.96	2.41	9.11	2.09	9.39
17	Kansas	9.30	4.26	2.18	9.84	0.97	7.78
18	Connecticut	9.18	2.66	3.46	10.06	1.65	9.77
19	South Dakota	9.17	2.74	3.35	10.29	0.22	8.82
20	Oklahoma	9.00	4.92	1.83	8.86	1.09	7.19
21	Alabama	8.86	3.01	2.94	8.69	1.31	8.45
22	Maryland	8.69	2.68	3.24	9.30	1.76	9.52
23	Wyoming	8.66	4.00	2.16	9.32	0.25	3.72
24	Vermont	8.60	2.35	3.66	9.34	0.19	9.08
25	Idaho	8.52	2.36	3.62	9.42	0.29	7.45
26	California	8.48	2.41	3.52	9.46	12.71	9.57
27	Maine	8.32	2.87	2.90	8.87	0.33	8.16
28	New Jersey	7.88	2.42	3.26	9.04	4.16	10.23
29	New Hampshire	7.81	1.42	5.52	10.98	0.39	8.87
30	Alaska	7.75	3.72	2.09	8.71	0.39	3.84
31	Wisconsin	7.74	2.84	2.73	9.21	1.61	8.23
32	Illinois	7.66	3.36	2.28	8.73	5.14	8.82
33	Montana	7.47	5.02	1.49	7.41	0.25	5.95
34	Nebraska	7.41	2.84	2.61	9.32	0.59	7.50
35	Iowa	7.19	3.46	2.08	8.61	0.96	8.59
36	Massachusetts	7.19	2.10	3.42	9.07	2.68	9.86
37	Louisiana	7.14	4.53	1.57	8.15	1.83	5.83
38	North Dakota	7.09	3.93	1.80	8.14	0.20	7.02
39	Mississippi	7.05	2.64	2.66	8.77	0.70	7.33
40	North Carolina	6.83	2.14	3.19	11.02	2.18	8.52
41	Ohio	6.80	3.29	2.07	8.07	4.09	8.14
42	Kentucky	6.64	3.17	2.09	8.55	1.07	7.08
43	Michigan	6.49	3.90	1.67	8.06	3.07	7.84
44	Pennsylvania	6.34	3.04	2.09	8.46	4.38	8.23
45	Dist. of Col.	6.34	3.56	1.78	7.41	0.65	13.81
46	Rhode Island	6.28	2.58	2.44	8.83	0.34	9.68
47	Indiana	6.05	2.54	2.38	7.93	1.93	7.74
48	Hawaii	5.90	1.92	3.07	8.30	0.46	9.01
49	New York	5.90	2.68	2.20	7.80	9.92	10.96
50	South Carolina	5.59	1.33	4.19	9.44	1.02	8.17
51	West Virginia	4.81	3.63	1.32	6.17	0.57	6.28

Source: based on data from BEA. The output growth contribution of IT capital is expressed in average yearly percentage points, all others are percentages.

Table 5.9: Average labor productivity growth contribution of it and traditional capital by state

Rank	*State*	*Productivity growth contribution of IT*	*% of productivity growth due to IT*	*Productivity growth contribution of non-IT capital*	*% of productivity growth due to non-IT capital*	*Growth rate of productivity*	*IT capital deepening*	*Non-IT capital deepening*	*TFP*
1	Colorado	9.78	9.82	12.15	12.19	4.19	7.54	0.35	77.99
2	Delaware	8.84	4.65	71.29	37.51	4.13	9.01	2.16	57.84
3	Georgia	8.33	5.14	22.86	14.10	4.85	8.27	0.94	80.76
4	Washington	8.21	7.55	30.62	28.17	3.72	7.66	0.82	64.28
5	New Mexico	8.12	5.86	-40.94	-29.54	4.13	7.68	-0.64	123.68
6	Virginia	8.08	11.07	24.06	32.98	3.32	7.82	0.86	55.95
7	Missouri	8.05	7.87	13.62	13.32	2.41	7.70	0.44	78.81
8	Texas	7.95	6.96	18.44	16.15	3.70	7.99	0.39	76.89
9	Kansas	7.87	10.16	1.75	2.26	2.18	8.33	0.04	87.58
10	Oklahoma	7.86	9.66	3.01	3.70	1.83	7.73	0.07	86.64
11	Arizona	7.80	5.89	-3.70	-2.80	5.72	6.81	-0.09	96.91
12	Tennessee	7.68	5.71	11.89	8.84	3.66	6.77	0.71	85.45
13	Arkansas	7.60	7.02	21.80	20.13	3.03	7.03	0.72	72.85
14	Connecticut	7.45	4.51	22.66	13.73	3.46	8.16	1.56	81.76
15	Oregon	7.44	4.45	13.61	8.14	3.87	8.00	0.38	87.41
16	Minnesota	7.43	5.99	1.16	0.94	3.39	7.81	0.04	93.07
17	Utah	7.10	7.30	-5.04	-5.19	4.60	6.88	-0.10	97.89
18	Alabama	7.08	5.70	24.51	19.72	2.94	6.95	0.71	74.58
19	Illinois	7.00	4.53	13.19	8.53	2.28	7.98	0.62	86.94
20	South Dakota	6.97	7.12	38.70	39.55	3.35	7.82	1.08	53.33
21	Montana	6.92	7.52	32.19	34.95	1.49	6.86	0.50	57.53
22	Maine	6.75	5.33	16.37	12.93	2.90	7.20	0.73	81.74
23	Maryland	6.65	5.88	20.07	17.73	3.24	7.12	0.65	76.39
24	Iowa	6.56	4.97	25.32	19.19	2.08	7.85	0.77	75.84
25	Wisconsin	6.55	4.96	18.18	13.79	2.73	7.79	0.62	81.25
26	California	6.39	4.91	24.17	18.56	3.52	7.13	0.87	76.53
27	Idaho	6.39	4.87	17.81	13.57	3.62	7.06	0.46	81.56
28	Louisiana	6.36	8.34	43.44	56.96	1.57	7.26	0.72	34.70
29	New Jersey	6.35	4.08	23.57	15.15	3.26	7.29	1.10	80.77
30	Ohio	6.25	4.53	12.96	9.39	2.07	7.41	0.47	86.08
31	Vermont	6.20	5.34	14.18	12.21	3.66	6.73	0.65	82.45
32	Nebraska	6.19	5.42	56.01	49.01	2.61	7.78	1.28	45.57
33	North Dakota	6.10	8.26	51.09	69.21	1.80	7.00	0.96	22.53
34	Florida	5.97	8.50	6.90	9.82	4.61	5.92	0.30	81.68
35	Michigan	5.93	6.49	14.36	15.70	1.67	7.37	0.52	77.81
36	Pennsylvania	5.85	4.11	8.67	6.10	2.09	7.8	0.32	89.79
37	Rhode Island	5.73	3.44	35.05	21.08	2.44	8.05	2.17	75.48
38	Mississippi	5.72	5.43	9.84	9.34	2.66	7.12	0.27	85.23
39	Massachusetts	5.64	3.62	25.53	16.38	3.42	7.12	1.11	80.00
40	Kentucky	5.53	8.34	12.75	19.26	2.09	7.12	0.45	72.40
41	New York	5.31	3.68	7.53	5.21	2.20	7.02	0.77	91.11
42	West Virginia	5.31	2.80	48.47	25.53	1.32	6.81	1.36	71.67
43	Dist. of Col.	5.27	9.94	4.46	8.41	1.78	6.17	0.18	81.65
44	North Carolina	5.26	6.93	25.00	32.99	3.19	8.48	1.19	60.08
45	Indiana	5.16	4.42	12.65	10.84	2.38	6.76	0.38	84.74
46	New Hampshire	5.13	2.69	56.12	29.46	5.52	7.2	1.95	67.85
47	Nevada	4.78	10.32	14.29	30.85	5.91	5.27	0.32	58.83
48	South Carolina	4.18	2.25	38.06	20.46	4.19	7.07	1.22	77.29
49	Hawaii	4.17	6.20	18.01	26.75	3.07	5.86	0.79	67.05

Note: Values are sorted in descending order by the percentage contribution of IT capital. All values are percentages, except the productivity growth contribution of IT and non-IT capital, expressed in average yearly percentage points. The states of Alaska and Wyoming were not included.

Ohio are ranked 34th, 44th, 17th, 37th, 7th, 42nd, 43rd and 38th (average ranking is 33rd). The correlation between a state's share of national IT capital stock and the contribution of this stock to productivity growth is negative although not significant (-0.133). The productivity paradox may again be explained with the convergence theory: IT capital highly contributes to growth in productivity when states start to accumulate IT capital. The magnitude of this contribution is then reduced as states converge to their ideal level of IT capital stock. However, when IT capital stock is considered nationally, its contribution to productivity growth seems lower because it is actually lower in states that own the highest share of this capital stock. Thus, long learning lags are needed to allow benefits from IT capital, bur rent dissipation make the returns to IT capital diminish over time as capital accumulates.

6. CONCLUSION

This study has shown the results from estimation techniques aimed at measuring the productive capacity of IT capital and its effect on output growth and labor productivity growth. These techniques were applied at various levels of analysis: national, sector, state detailed and aggregated industry levels.

The first equation (5.1) measured an output elasticity of IT capital valued at up to 21% (Table 5.1). Lehr and Lichtenberg (1999), using a similar model, found an elasticity of IT capital between 4% and 17%. They also showed that IT capital exhibited excess returns to investment, and my results are similar, although these excess returns may be mostly due to state and time effects.

Table 5.10: Values of output growth contribution of it capital from various empirical studies

Authors	*Period Studied*	*Output growth contribution of IT capital*
Oliner and Sichel (1994)	1970-1992	0.16
Oliner and Sichel (2000)	1974-1995 1996-1999	0.27 0.62
Brynjolfsson and Hitt (1993)	1987-1991	0.35
Jorgenson and Stiroh (1995)	1979-1985 1985-1992	0.52 0.38
Jorgenson and Stiroh (1999)	1973-1990 1990-1996	0.12 0.16
Jorgenson and Stiroh (2000)	1973-1995 1996-1998	0.17 0.36
Wehlan (1999)	1980-1995 1996-1998	0.37 0.82
Kiley (1999)	1974-1984 1085-1998	-0.34 -0.27
Lau and Tokutsu (1992)	1973-1990	1.50

Note: Measured in percentage points per year.

Information technology capital is also found to have contributed to output growth between approximately 0.05 and 0.15 percentage points across states (Table 5.8). Various authors have found values ranging from –0.34 to +1.50, as reported in Table 5.10. Hence, my results fall into this range, but are specific to the methodology and data I have used. Oliner and Sichel (1994) have found that IT capital contributed 0.16 percentage points per year to output growth during the period 1970-1992, which is close to my results. Finally, the contribution of IT capital to labor productivity growth is estimated between 0.04 and 0.10 percentage points per year. The percentage of output and labor productivity growth due to IT capital varies across states from 1% to 11%. Hence, IT capital has proven to be a productive input, even if its small share of total capital prevented it from having had higher effects on growth.

An interesting finding that helps understand the national productivity paradox is that the productivity effects of IT capital seem to be lower for states that own the highest share of national IT capital stock (such as California and New York). This confirms the hypothesis of redistributions of gains of IT capital among states. Therefore, the productivity paradox may have been only a problem at the national level.

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Y A-T-IL UN PARADOXE DE LA PRODUCTIVITÉ AU NIVEAU RÉGIONAL ? UNE ÉTUDE EMPIRIQUE DE LA CONTRIBUTION À LA CROISSANCE DU STOCK DE CAPITAL AU NIVEAU DES ÉTATS AMÉRICAINS ENTRE 1977 ET 1997

Résumé *- Le rôle des nouvelles technologies de l'information et de la communication (NTIC) est estimé dans l'économie américaine, au travers de leurs effets sur les différences régionales de productivité du travail. L'étude permet d'apporter des éléments nouveaux au débat sur le "paradoxe de la productivité", selon lequel l'investissement massif en nouvelles technologies n'a pas entraîné d'augmentation sensible de la productivité nationale. Les NTIC sont considérées comme une catégorie particulière de capital, différente du capital "traditionnel". Une analyse en coupe des fonctions de production des États américains entre 1977 et 1997 montre que le capital NTIC est un facteur productif, plus que le capital traditionnel, et qu'il a* *contribué à la croissance du produit à hauteur de 10 points de pourcentage annuel moyen. Cependant, de larges différences apparaissent entre les États américains. La contribution à la croissance semble moindre dans les États possédant la plus grosse part du stock technologique national (huit États se partagent la moitié du stock total). Le paradoxe s'expliquerait donc en partie par des différences régionales, qui n'apparaissent pas dans la comptabilité nationale.*

¿EXISTE UNA PARADOJA DE PRODUCTIVIDAD AL NIVEL REGIONAL? UN ESTUDIO EMPÍRICO DE LA CONTRIBUCIÓN DEL CRECIMIENTO DEL CAPITAL SOCIAL AL NIVEL ESTATAL EN LOS ESTADOS UNIDOS ENTRE 1977 Y 1997

Resumen – *El papel de las nuevas tecnologías de la información y de la comunicación (TICs) se calcula en la economía americana, a través del efecto que tienen sobre las diferencias regionales de productividad al trabajo. Esta investigación nos permite llevas elementos nuevos en el debate sobre la "paradoja de la productividad", según la cual la inversión masiva en nuevas tecnologías no engendró un aumento real de la productividad nacional. Se consideran las TICs como una categoría particular de capital, distinta del capital "tradicional". Un análisis en corte de las funciones de producción de los Estados americanos entre 1977 y 1997 muestra que el capital TICs es un factor productivo, más que el capital tradicional, y que contribuyó al crecimiento del producto de 10 puntos por encima del porcentaje anual medio. Mientras tanto, aparece que existen muchas diferencias entre los Estados americanos. La contribución al crecimiento parece menos en los Estados que tienen la más amplia parte del capital tecnológico nacional (ocho Estados se comparten la mitad del capital total). La paradoja se podría explicar parcialmente porque hay diferencias regionales que no aparecen en la contabilidad nacional.*