ICT AND PRODUCTIVITY OF THE MANUFACTURING INDUSTRIES IN IRAN

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ABSTRACT

This paper extends the existing evidence on the relationship between Information and Communication Technology (ICT) and productivity using data from the entire Iranian manufacturing sector (22 industries) over the period 1993–1999. Estimates of efficiency using panel data confirm the positive and significant impact of ICT investments on productivity. Our finding is consistent with the most recent literatures in the context of developed and a few middle-income developing countries. Human capital and increasing ICT capital are probably two determining factors in gaining the positive payoffs from ICT investments in Iran.

Keywords: ICT, Technical Efficiency, Stochastic Frontier Production Function, Iran.

1. INTRODUCTION

The effect of Information and Communication Technology (ICT) on firm performance has been the subject of many studies during the last two decades (Strassman, 1985; Baily, 1986; Roach, 1988; Brynjolfsson et al., 2000; Oliner et al., 2000; Jorgenson, 2001). While earlier studies showed mixed results, starting from the mid 90s, more studies have found the positive and significant returns to ICT investments. With the growing scale of ICT investment, researchers have tried to perform more careful analysis using larger datasets and more sophisticated methodologies. Consequently, more studies have shown positive and significant impacts from ICT investments at firm and country level (Brynjolfsson et al., 2000; Oliner et al., 2000; Jorgenson, 2001).

For example, Brynjolfsson et al. (2000) showed that payoffs to ICT investment occur not just in labor productivity but also in Multi Factor Productivity (MFP) growth, and that the impact on MFP growth is maximized after a lag of four to seven years in the US. Gilchrist et al. (2001), using the same dataset, focused on the manufacturing companies in the sample and suggested that ICT has significant impacts on labor productivity and on MFP growth in the durable goods sector, which exceeds the impact that would be predicted by its factor share. Most of the foregoing trends have also been found in other developed countries of Europe and Asia at firm and country level studies (Schreyer, 1999 for G-7 countries; Greenan, et al., 2001 for France; O'Mahony et al., 2003 for the US and UK; Timmer, et al., 2003 for the European Union; Leeuwen et al., 2003 for Dutch firms).

It is difficult for less developed countries to isolate themselves from the changes occurring due to the developments in ICT in the global village. Hence, they need to fully understand the pervasive nature of these changes and the productivity impacts of ICT. Therefore, the formulation and implementation of comprehensive ICT strategies have become critical for the less developed countries. This is emphasized by the fact that the resources to support the operation of ICT are usually scarce (Lu et al., 1990; Shahabudin, 1990; Kahen, 1995).

A few of the country level studies came to the conclusion that wealthier, industrialized countries showed a positive and significant relationship between ICT, growth and productivity, but that there was no evidence of such a relationship for developing countries (Dewan et al.,1998, 2000; Pohjola, 2001). It is suggested that this gap is due to the low levels of ICT investment relative to GDP in developing countries, and to the lack of complementary assets such as the necessary infrastructure and knowledge base to support effective use of ICT. However in the context of a number of middle income and less developed countries (such as Argentina, Brazil, Mexico, South Korea, and Malaysia) few studies have indicated significant ICT contribution to firm productivity. Successful experience of these countries has shown that ICT can cross the boundaries of organizations and reach the national level in order to play a fundamental role in technological development (Kahen, 1995).

For example, in Korea, a widespread ICT strategy has been a key driver in the miracle economic recovery from the financial crisis; the ICT industry's contribution to GDP growth rose from 4.5% in 1990 to 50.5% in 2000 (Hanna, 2003; Chao, 2000). Costa Rica's economic growth reached to 8.3 percent in 1999 – the highest in Latin America, derived from the exports from the microchip industry, which accounts for 38 percent of all exports. Similarly, software is a profitable export for India. India's software exports have reached US $12.5 billion (InformationWeek, June 3, 2004). In Latin America and the Caribbean, high-tech exports amount to 12 percent of manufactured exports (Granville et al., 2001; Moss, 1987; Hepworth, 1987; Gillespie et al., 1988). Mixed empirical results are an invitation for more rigorous studies that analyze the impact of ICT investments on productivity and other performance measures in less developed countries.

So far, the value of ICT has been measured in many ways such as financial performance measures, economic performance measures and other measures like customer satisfaction. Due to the significant role of ICT in the firm's production process, some studies dealt with ICT as a production factor. However, not many studies have considered economic performance measure like technical efficiency of the production process (Shao et al., 2001). Banker et al. (1990) employed a Data Envelopment Analysis (DEA) to examine the operational efficiency of a chain of fast food restaurants in US and found out that the restaurants equipped with the technology were less likely to be inefficient. In a more recent study Shao et al. (2001) used stochastic frontier production function on a firm-level panel data for US firms and showed that ICT has a significant positive effect on technical efficiency and hence contribute to the productivity growth in organizations.

In production theory, technical efficiency and productivity are two related concepts, but they also represent two different performance measures. With the production technology as given, technical efficiency is relevant to getting the most out of a set of input resources; productivity, on the other hand, refers to the effective usage of overall resources, without making any assumption for the production technology. Therefore, an essential relationship exists between these two constructs (Grosskopf, 1993; Lin et al., 2000). Productivity growth is the net effect of the change in technical efficiency and the shift in the production frontier, or productivity growth=(technical efficiency change)×(technological change). In other words, technical efficiency is one important factor in deciding a firm's productivity, with the other one being technological change (Shao et al., 2001).

Therefore, in this paper we apply this approach by looking into the effects of ICT on technical efficiency of a representative sample of manufacturing industries in Iran, a middle-income OPEC (Organization of the Petroleum Exporting Countries) country which is trying to diversify its economy. In particular, prior research argued that theories developed in the context of industrialized countries need to be reexamined in the context of developing countries (Austin, 1990) because these countries may have very different economic and regulatory environments (Dewan et al., 2000; Jarvenpaa et al., 1998). Consequently, it is important to add an international dimension to the investigation of ICT and productivity, extending beyond the US and Europe to encompass the experience of the less developed countries.

The paper is organized as follows. Section 2 provides a brief overview of the role of ICT in developing countries in general and Iran in particular. We explain methodology and the data in section 3 and section 4 respectively. In Section 5 the estimation results are discussed. Having done that, concluding remarks and implications appear in the final section.

2. INFORMATION TECHNOLOGY IN IRAN

From the early 90s, ICT has diffused rapidly in developed industrialized countries but rather slowly in developing ones, which led to the ICT gap or digital divide between developed and developing countries. Table (1) presents information on ICT diffusion in different regions of the world. The Newly Industrialized Economies (NIEs) are in a much more advanced level than the other developing countries in Southeast Asia, South Asia, Central Asia and the Pacific. It looks obvious that the degree of ICT diffusion has a strong positive correlation with the level of income per capita among these countries.

Iran is the second largest economy in the region and the second largest OPEC oil producer which has the world's second largest reserves of natural gas. Developments in education have been positive in recent years. English is taught at many schools starting as early as primary education, particularly in private schools. In 1999 the literacy rate of the population has reached 80.4 percent. It has a very young population structure with about 60 percent under 20 and highly educated people, which make it a very good case for ICT expansion (Who's top? The Economist, January 18, 1997).

Iran's Internet link started in the early 90s and has been developing very rapidly since the year 2000. According to a report by the Middle East Economic Digest (MEED), Iran was investing approximately $US2.3 billion per year on main telephone systems until the year 2000; the second highest in the Middle East and North Africa (MENA) after Turkey− $US5 billion (Iran's Extended Telecommunication Project, the World's Top Five, May 20, 1995, http://netiran.com/). As for the number of PCs per 1,000 inhabitants, 69.7 was a well-informed estimate for the year 2001 according to the world development report 2001.

Table 1. Information and Communications Infrastructure, 1995 – 2001
(Per 1,000 inhabitants)

Country Groups	Personal Computers	Internet Users	Telephone Mainlines	Mobile Phones
Income Breakdown				
High-income OECD	363	360	574	690
Developing countries	34	37	104	94
Least developed	4	3	7	8
Regional Breakdown				
Northern America	623	467	660	382
Western Europe	325	345	572	747
East Asia and Pacific	158	177	222	278
Eastern Europe & Central Asia	81	65	232	199
Middle East and North Africa	62	61	147	163
Latin America and the Caribbean	49	63	145	142
Sub-Saharan Africa	12	9	19	30
South Asia	4	4	20	9

Sources: International Telecommunication Union (2002), created by Pohjola (2003)

At least six Iranian firms are engaged in manufacturing computers in the domestic market, while almost 500 firms are active in software production. However, government policies restricting computer and software imports have enabled the Iranian firms to grow in the field of software. These companies are now directing their efforts toward manufacturing diverse software, mostly needed by domestic markets (http://netiran.com, One billion dollars in investment needed to boost electronic products, May 6, 1995). It is one of the fastest growing Telecommunications markets and the current mobile usage far exceeds its capabilities. The number of mobiles and fixed telephone lines are predicted to grow from the current 3.5 million and 16 million to 40 million and 33 million by the end of fourth development plan (2005-2010). Number of Internet users was estimated 5.5 million in September 2004, and will grow to more than 30 million by the end of the upcoming fourth development plan (http://www.payvand.com/news/04/sep/1181.html).

Activities on e-government have been commenced since year 2000, and electronic transmission of information between governmental organizations, will be conducted by establishing a separate network with a wide bandwidth for the connection of all governmental centers (Asia-Pacific Summit on the Information Society, 2000). ICT is playing an increasing role in growth, capital investment, and other aspects of the economy. However, it has been mostly used in the manufacturing industry, services, and transportation sectors of the economy. Very few studies have been conducted on the relationship between ICT and economic growth in Iran (Moshiri et al., 2004), but none at the sectoral level. In this paper, we focus on the manufacturing industry to analyze the impact of ICT on productivity. In the next section, we will overview the Iranian manufacturing industries briefly.

2.1. An Overview of the Iranian Manufacturing Industries

The manufacturing industry in Iran composes about 20 percent of the GDP, ranking second after the services sector. Iran's industrialization started in mid 70's, when the first oil price hike brought in huge capital. Many heavy and light industries were established producing goods to substitute for imports. The economy and the manufacturing industry sector have undergone a lot of changes for the past three decades, but we can summarize the main features of the sector as follows.

1. The manufacturing industries are heavily dependent on oil revenue as a major source for financing the imports of the raw materials and intermediate goods. Therefore, the sector's fluctuations can mostly be explained by the oil price changes.
2. The government is very involved in the sector, as it is in the rest of the economy. The government owns and runs the most important manufacturers, allocates domestic and foreign credits to the sector by banks most of which are public, highly regulates the international trade by setting quotas and tariffs (Hadizonooz, 2000).
3. Being dependent on the foreign technology, the manufacturing industry does not have an active R&D program to develop new technology and to lower costs.
4. The sector, like the rest of the economy, was badly affected by the revolution and then the eight-year war with Iraq. Many plants had to shut down or to decrease their already low capacity utilization. The growth in the value added of the sector which was 16 percent on average in 1974-78, declined to 5 percent in 1993-1997. Also, the capacity utilization was only 40 percent in 1987 (Management and Planning Organization-MPO, Iran's First Socio-Economic Development Plan, 1988).
5. Being supported by the import substitution and self-sufficiency policies, the manufacturing industries did not have to compete in the world market, which requires the quality improvement and lower costs.
6. The post war policies pictured in the three five year socio-economic development plans were designed to improve the state of the economy by increasing the growth and decreasing the unemployment. The major policies adapted during the plans can be highlighted as follows.
    a. Removing price control policy, particularly in the manufacturing industries sector.
    b. More openness by encouraging the export of goods produced in non-oil sectors and alleviating import restrictions.
    c. Privatization in the manufacturing sector, activating the stock market which allows for more diversified and competitive financing resources.
    d. New and lighter regulations on the foreign investment in the sector.

The high oil price along with the new economic adjustment and stabilization policies adapted during the last three five-year plans have led the manufacturing industries to grow significantly and to improve the quality of the products. The main challenges facing the old but reestablished as well as the new industries started since 1987 are adapting the new technology, including ICT, and competing in the world market by increasing the quality of the products and lowering the costs. This is particularly important as the less and less oil revenues are available to the sector making it to stand on its own feet in order to survive.

3. Empirical Analysis

3.1. Stochastic Frontier Production Function

The methodology adopted to analyze industry level efficiency is the stochastic frontier production function, which has been extensively used in the empirical analysis of technical efficiency. An industry that operates on the frontier is said to produce its potential or maximum output by following the 'best practice' techniques, given the technology. The production frontier is the theoretical maximum output that can be achieved using every possible combination of inputs. Hence, the frontier can be thought to represent best practice technology. The level of inefficiency can then be measured by comparing the existing output with the theoretical maximum output.

A value of 1 will represent the best practice technology and values between 0 and 1 a measure of inefficiency (Dhawan et al., 1997). Farrel (1957) first made operational the measurement of efficiency and characterized the ways in which a production unit can be inefficient. It can be technically inefficient by obtaining less than the maximum output available from whatever bundle of inputs it has chosen to employ. Figure 1 shows a production frontier f with one input X and one output Y.

Suppose the firm operates at point A. According to the production frontier, the firm can increase its output level to B using the same amount of input X_1 and hence the distance AB can be regarded as technical inefficiency for the firm. We can also use the ratio of AC/BC (=1- AB/BC) to represent the technical efficiency. This ratio of technical efficiency will take a value between zero and one, with a higher score implying higher technical efficiency (Shao et al., 2001). Regression analysis has been used to estimate productivity by the stochastic frontier analysis method.

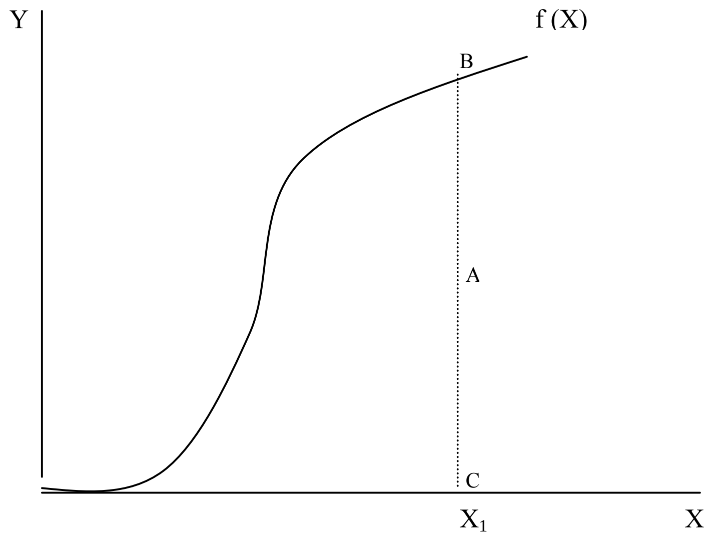

Figure 1. Production Frontier f(x) and technical efficiency (Shao et.al. 2001)

The stochastic term of the production regression equation represents the factors other than labor and capital affecting the output. Where initial estimates of efficiency assumed that the error term was not affected in any way by statistical 'noise' and thus represented inefficiency, the stochastic frontier model decomposes the error term into two parts, as developed by Aigner et al. (1977). One part captures the effects of random shocks and noise, while the other part is a one-sided term reflecting inefficiency, which is non-positive. The inefficiency disturbance reflects the fact that each firm's output must lie on or below its frontier.

3.2 Empirical Models

Following Shao et al. (2001), we estimate the impact of ICT on the productivity in two stages. In the first stage, we estimate a production function and extract the productivity series from the residuals. Then, in the second stage, we run a separate regression to estimate the impact of ICT on productivity. In the first stage, we use two different well-known production functions, namely the Cobb-Douglas production function and Translog Production function. The Cobb-Douglas production frontier has been one of the most frequently used functional specifications in the research of production economies. Typical Cobb-Douglas with two inputs, labor (L), and capital (K) can be written as follows.

$$Y_{it} = \alpha K_{it}^{\beta_k} L_{it}^{\beta_l} e^{v_{it} - u_{it}} \qquad \text{(i=1,…, N and t=1,…,T)} \tag{1}$$

Where
Y_{it} =output produced (in value) by the i-th manufacturing industry in t-th year;
L_{it} = labor (number of employees in i-th industry in t-th year);
K_{it} = capital (in value in i-th industry in t-th year);
the β_i's are unknown parameters to be estimated.Taking natural logarithm we have the following equation:

$$\ln(Y_{it}) = \beta_0 + \beta_1 \ln(L_{it}) + \beta_2 \ln(K_{it}) + v_{it} - u_{it} \tag{2}$$

The stochastic error term of the regression consists of the two terms, v_{it} and u_{it}. The random errors v_{it} account for measurement error and other random factors on the output level together with the combined effects of unspecified input variables in the production frontier. The statistical errors v_{it}s are assumed to be independently and identically distributed normal random variables with mean zero and constant variance σ^2. In contrast, the residual component u_{it} represent the effects of events caused by the firm, such as resource mis-application, information overload, poor decision making, ineffective communication, and so on (Shao et al., 2001).

These technical inefficiencies u_{it}s are assumed to be non-negative random variables of independently truncated normal distributions. The underlying normal distribution for u_{it} is $u_{it} \sim N(\mu_{it}, \sigma_u^2)$. The truncated normal distribution of u_{it} requires technical inefficiency be non-negative only and dependent on some firm-specific characteristics. Therefore, Technical efficiency (TE) is given by the ratio of observed output to frontier output:

$$TE_{it} = \frac{y_{it}}{f(X_{it}, \beta)\exp(v_{it})} = \exp(-u_{it}) \tag{3}$$

We also consider the more flexible translog functional form, which relaxes the restrictions such as fixed returns to scale, on the production function (Shao et al., 2001). The three input translog stochastic production frontier can be specified as:

$$\ln(Y_{it}) = \beta_0 + \beta_1 \ln(L_{it}) + \beta_2 \ln(K_{it}) + \beta_3 T + \beta_4 \frac{Ln^2 L_{it}}{2} + \beta_5 \frac{Ln^2 K_{it}}{2} + \beta_6 \frac{T^2}{2} + \beta_7 \ln L_{it} T + \beta_8 \ln K_{it} T + \beta_9 \ln K_{it} \ln L_{it} + v_{it} - u_{it} \tag{4}$$

where all the variables and the assumptions underlying the random error v_{it} and the technical inefficiency are the same, and T is trend variable used as an approximation for technology change. Since u_{it}s are non-negative in Equations (2) and (4) it can be inferred that $-u_{it} \le 0$ and hence, $0 \le e^{-u_{it}} \le 1$, which corresponds with the definition of the ratio measure for technical efficiency being a value between zero and one. In the second stage, we would like to analyze the impact of ICT on productivity, testing the following hypothesis:

H_0: ICT investment has a positive effect on the technical efficiency of the manufacturing industries in Iran.

To model the impact of ICT on technical efficiency in the production process, we regress the obtained technical efficiency scores $e^{-u_{it}}$ against their corresponding ICT investments.

$$e^{-u_{it}} = \alpha_0 + \alpha_1 ICT_{it} + \varepsilon_{it} \quad (5)$$

If the coefficient estimate for α_1 is significantly positive, we can conclude that ICT has a positive effect on technical efficiency.

4. DATA

The data used in this study covers the entire Iranian manufacturing sector over the period 1993–1999. The data set is a panel of 22 industries based on ISIC (International Standard Industrial Classification) codes in 7 years. The introduction of a panel data dimension allows using both cross-sectional and time series information to test the relationship between ICT investment and productivity. In particular, it provides the researcher with a large number of observations, increasing the degree of freedom and reducing the multi-collinearity among explanatory variables.

The data set includes value added, labor, capital, and ICT investment. The source of data was the Iranian National Bureau of Statistics. Output (Y) is given by value added at 1996 constant prices. Labor (L) refers to the total number of persons engaged in the manufacturing industry. In the absence of data on services provided by capital, we have to estimate stock of fixed capital. Capital refers to the net stock of investment in reproducible fixed assets.

The Perpetual Inventory Method (PIM) has been used to produce estimates of the value of the stock of capital assets used in the production process. The PIM produces annual estimates of capital stock at constant by accumulating past flows of expenditure on Gross Domestic Fixed Capital Formation. ICT investment refers to the annual investment in IT hardware for office machines, data processing equipment, data communications equipment, and of IT software and IT services, plus Telecommunications equipment and services. A statistical summary of the data including the estimate of capital is presented in Table (2). The individual industries included in the data set are presented in Table (3).

Table2- Summary Statistics of the Variables

Variable	Definition	Mean	SD	Min	Max
Y	Value added	1504.527	1739.119	29.048	8334.817
L	Labor	34158.44	37491.8	360	154871
K	Capital	2759.34	3963.402	23.30	22313.33
ICT	ICT investment	3.38	3.459161	0.09	14.43

SD: Standard Deviation. Y, K, and ICT are measured in Fixed 1996 prices and in the billions of Iranian Currency (Rials). Number of Observations is 154.

Table 3- List of Industries

Industry	ISIC Code
Manufacture of Food products and beverages	15
____Tobacco products	16
____Textiles	17
____Wearing apparel; dressing and dyeing of fur	18
____Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness, and footwear	19
____Wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	20
____Paper and paper products	21
____Publishing, printing and reproduction of recorded media	22
____Coke, refined petroleum products and nuclear fuel	23
____Chemicals and chemical products	24
____Rubber and plastic products	25
____Other non – metallic mineral products	26
____Basic metals	27
____Fabricated metal products, except machinery and equipment	28
____Machinery and equipment n.e.c.	29
____Office, accounting and computing machinery	30
____Electrical machinery and apparatus n.e.c.	31
____Radio, television and communication equipment and apparatus	32
____Medical, precision and optical instruments, watches and clocks	33
____Motor vehicles, trailers and semi- trailers	34
____Other transport equipment	35
____Furniture; manufacturing n.e.c.	36

Source: Statistical Center of IRAN (ISIC rev3 is abbreviation for International Standard Industrial Classification).

5. ESTIMATION RESULTS AND DISCUSSION

The parameters of the stochastic frontier production function are estimated using the asymptotically efficient maximum-likelihood (ML) method by FRONTIER 4.1 computer program (Coelli, 1996) for the panel data.[1] The results are presented in Table (4) and (5). Table (6) presents the coefficient estimates for α_1 from the efficiency model in the second stage. The coefficient estimates for α_1 is significantly positive with the P-value <0.01. Therefore, we do not reject the null hypothesis H_0 with a confidence level of 99%. It means ICT investment has a positive effect on the industries' technical efficiency in the production process.

[1] The FRONTIER package uses a three-step estimation method to obtain the final maximum likelihood estimates; in the first step OLS estimates are obtained. Secondly, a two-phase grid search conducted for a parameter representing the ratio of inefficiency variance to the composite inefficiency and error variance whilst setting other parameters equal to their OLS counterparts. Thirdly, these values are used as starting values in an iterative process using the Davidson-Fletcher-Powell Quasi-Newton method to obtain maximum likelihood estimates.

Table 4 – Ordinary Least Squares Estimation (OLS)
Cobb-Douglas (CD) and Translog (TL) Stochastic Production Frontier Models

Variable Description in natural logs	Parameter	Cobb-Douglas	t statistics	Translog (TL)	t statistics
Constant	β_0	-3.05 (0.52)	5.82	4.80 (3.39)	1.41
L: Labor	β_1	0.86 (0.09)	8.97	-2.30 (1.36)	1.69
K: Capital	β_2	0.16 (0.07)	2.11	2.33 (1.02)	2.29
T: Time	β_3	-	-	-0.19 (0.29)	0.66
L^2: $(\text{Labor})^2$	β_4	-	-	0.31 (0.14)	2.17
K^2: $(\text{Capital})^2$	β_5	-	-	0.13 (0.08)	1.63
T^2: $(\text{Time})^2$	β_6	-	-	0.004 (0.01)	0.26
LT: (Labor × Time)	β_7	-	-	0.03 (0.05)	0.67
KT: (Capital × Time)	β_8	-	-	-0.02 0.04	0.54
LK: (Labor × Capital)	β_9	-	-	-0.41 (0.21)	1.99
Sigma-squared	σ^2	0.38		0.38	
Log-likelihood		-144.48			-140.48
Number of Observations		154		154	

Notes: Estimates were obtained using the software package FRONT41from the first step. Standard errors are in parentheses.

Table 5 – Maximum Likelihood Estimation (MLE)
Cobb-Douglas (CD) and Translog (TL) Stochastic Production Frontier Models

Variable Description in natural logs	Parameter	Cobb-Douglas	tstatistics	Translog (TL)	t statistics
Constant	β_0	-2.93 (0.5)	-5.8	4.97 (0.98)	5.06
L: Labor	β_1	0.84 (0.09)	9.23	-0.91 (0.46)	2.01
K: Capital	β_2	0.16 (0.07)	2.31	0.72 (0.52)	1.38
T: Time	β_3	-	-	-0.01 (0.13)	0.08
L^2: $(\text{Labor})^2$	β_4	-	-	0.11 (0.06)	1.92
K^2: $(\text{Capital})^2$	β_5	-	-	0.006 (0.03)	0.16
T^2: $(\text{Time})^2$	β_6	-	-	0.01 (0.007)	1.58
LT: (Labor × Time)	β_7	-	-	0.05 (0.02)	2.26
KT: (Capital × Time)	β_8	-	-	-0.06 (0.02)	3.25
LK: (Labor × Capital)	β_9	-	-	-0.06 (0.09)	0.67
sigma-squared	σ^2	0.37 (0.04)	8.48	0.75 (0.14)	5.3
gamma	γ			0.92 (0.01)	73.46
Mu	μ			1.6 (0.3)	5.4
Eta	η			-0.11 (0.02)	-5.1
Log-likelihood		-143.86		-38.38	
Number of Observations		154		154	

Notes: Estimates were obtained using the software package FRONT41 (Coelli, 1996).

Table 6- Panel Estimation of α_1 with ICT investment as the dependent Variable

Dependent Variable: Technical Efficiency Scores (TE)				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
Constant	*0.997246*	*0.008611*	*115.8146*	*0.0000*
ICT	*0.057949*******	*0.003644*	*15.90396*	*0.0000*
IND1	-0.172894	0.017702	-9.766750	0.0000
IND2	0.001085	0.013728	0.079034	0.9371
IND3	-0.161329	0.017252	-9.351186	0.0000
IND4	-0.001060	0.013731	-0.077224	0.9386
IND5	-0.046043	0.015020	-3.065514	0.0026
IND6	-0.026452	0.013866	-1.907638	0.0586
IND7	-0.074418	0.014604	-5.095861	0.0000
IND8	-0.079868	0.014724	-5.424261	0.0000
IND9	-0.088788	0.014936	-5.944423	0.0000
IND10	-0.186523	0.018256	-10.21729	0.0000
IND11	-0.108576	0.015469	-7.018728	0.0000
IND12	-0.171534	0.017648	-9.719498	0.0000
IND13	-0.180603	0.018012	-10.02661	0.0000
IND14	-0.129884	0.016131	-8.051670	0.0000
IND15	-0.159537	0.017184	-9.283902	0.0000
IND17	-0.107664	0.015443	-6.971698	0.0000
IND18	-0.039086	0.014001	-2.791601	0.0060
IND19	-0.031193	0.013912	-2.242179	0.0266
IND20	-0.137348	0.016383	-8.383685	0.0000
IND21	-0.062067	0.014357	-4.323129	0.0000
IND22	-0.053589	0.015356	-3.489746	0.0007
R-squared	0.658333	Mean dependent var		0.942216
Adjusted R-squared	0.603977	F-statistic		12.11148
S.E. of regression	0.029985	Prob(F-statistic)		0.000000
Sum squared resid	0.118685			
Log likelihood	333.4378			
Durbin-Watson stat	1.409439			

Note: *** denotes significant at 1% significance level. INDs are the dummy variables for capturing the industry specific effects, with IND16 (Manufacturing of office, accounting, and computing machinery) being the reference. All coefficients of INDs, but IND 2 and IND4, are negative and significant, indicating that the specific effect of the IND16 is significantly greater than the other industries. The IND2 (Manufacturing of tobacco products) is positive but insignificant, and IND4 (Manufacturing of wearing apparel, dressing, and dyeing of fur) showing that these industries do not have a greater specific effect than the office, accounting and computing industry in the context of the ICT impacts on the productivity.

As mentioned earlier, previous studies which did not find positive impacts of ICT on productivity for developing countries, assume that this was due to the low levels of ICT investment relative to GDP, and to the lack of complementary assets such as the necessary infrastructure and knowledge base to support effective use of ICT. However it seems the story for middle-income developing countries is different. In agreement with a few studies on the developing countries such as Brazil, India, Mexico, and Malaysia (Hanna, 2003; Granville et al., 2001; Moss, 1987; Hepworth, 1987; Gillespie et al., 1988), our study indicate significant positive ICT contribution to manufacturing industries productivity, which means aggregate ICT investment has a positive and significant effect on industries' efficiency.

The reason to find positive association between ICT and productivity here could be related to using more recent panel data with increased level of ICT investment, and more improved econometric tools. Perhaps as suggested by Kohli et al. (2003) researchers should gather larger samples comprising of longitudinal or panel data to assess the effects of ICT payoff, since panel data can often improve the accuracy of the results because they can control for firm (or industry) specific effects. It could also be explained by the fact that firms have learnt to apply ICT capital more efficiently. Moreover, this positive effect can to a certain extent be attributed to the rate of capital accumulation. However, this by no means implies that pure factor accumulation as such will necessarily lead to high rates of technical efficiency, since the larger amounts of labor and capital inputs could be misallocated.

As suggested by Shao et al. (2001), strong support from top management, effective ICT strategies, innovative organizational culture, skilled ICT personnel, and other resources are essential to help utilize the promised benefits of ICT. Kahen et al. (1994) argue that although developing countries significantly invest in ICT, the returns from these investments have fallen short of their potential. Since inappropriate choice of applications and inadequate consideration of organizational and environmental factors in the formulation and implementation of ICT strategy can cause a form of inappropriate resource allocation (Bjorn-Andersen et al., 1990; Jones, 1985; Todaro, 1985; Hill, 1986).

According to Kahen (1995), “To improve productivity, ICT can be employed among all different sectors of the economy due to its specific characteristics. However, it should not be regarded as technical systems; rather it should be considered as the human-oriented and social systems in which technology is only one of the elements. A clear understanding of the role, function, and process of information in organizations should precede the application of ICT in developing countries in order to gain positive payoffs from these investments”.

As mentioned earlier, Iran is increasingly investing in its ICT infrastructure, the second highest in the Middle East and North Africa after Turkey. Table (7) shows that the level of ICT infrastructure and the human capital in Iran is at a rather higher level compared to most of the developing countries in the region. As such, human capital and ever-increasingly ICT capital are probably two determining factors in gaining the positive payoffs from ICT investments in Iran based on capital-skill complementarity hypothesis.

Table 7- Information and Communications Infrastructure (Per 1,000 populations) and Human Capital

Country	Telephone Mainlines 1998	Personal Computers		Scientists and Engineers in R&D per million people (1987-97)	Secondary School Enrollment (%) (1999)
		1998	2001		
Iran	**112**	**31.9**	**69.7**	**560**	**80.04**
Algeria	53	4.2	7.1	-	66.9
Azerbaijan	89	-	-	2791	80.1
Bangladesh	3	-	1.9	52	53.7
Brazil	121	30.1	62.9	168	103.2
China	70	8.9	19.0	454	62.8
Egypt	60	9.1	15.5	459	83.5
Estonia	343	34.4	81.2	2017	106.9
Greece	522	51.9	5.8	773	94.6
India	22	2.7	11.0	149	49.9
Indonesia	27	8.2	32.8	182	54.8
Jordan	86	8.7	-	94	87.6
Kazakhstan	104	-	56.2	-	86.9
Lebanon	194	39.2	126.1	-	76.2
Malaysia	198	58.6	68.7	93	98.8
Mexico	104	47.0	13.7	214	73.4
Morocco	54	2.5	6.8	-	39.3
Nigeria	4	5.7	32.4	15	-
Pakistan	19	3.9	4.1	72	39.04
Philippines	37	15.1	21.7	157	-
Poland	228	43.9	85.4	1358	98.4
Portugal	413	81.3	117.4	1182	112.04
Romania	162	10.2	35.7	1387	80.1
Saudi Arabia	143	49.6	62.7	-	68.4
Syria	95	1.7	16.3	30	-
Tajikistan	37	-	-	666	75.9
Thailand	84	21.6	27.8	103	78.9
Tunisia	81	14.7	23.7	125	74.5
Turkey	254	23.2	40.7	291	57.7
Ukraine	191	13.8	18.3	2171	-
Uzbekistan	65	-	-	1763	-
Yemen	13	1.2	1.9	-	40.03

Sources: World Development Report (2000/2001) and World Development Indicators (2003)

Labor demand studies have well-acknowledged and documented complementarity between ICT and skilled workers (Bermanet al., 1994; Autoret al., 1998). Bresnahanet et al. (2002) also assume that human capital is a key element in the explanation of the ICT productivity paradox. As individuals learn to waste less time and raw materials in producing a given volume of output, efficiency increases. Referring to the idea of capital-skill complementarily (Griliches, 1969; Lucas, 1990), Bresnahanet et al. (2002) split their data into four categories according to whether firms are high or low on ICT and human capital and try to resolve the productivity paradox.

They argue that too much attention has been paid to investments in hardware and software and too little attention has been paid to the human capital structure in the firms. They also find that the balance between both ICT and human capital is crucial such that firms with high levels of both ICT and human capital are found to be the most productive. Furthermore firms with low levels of both ICT and human capital are shown to be more productive than firms that are high on ICT and low on human capital, or vice versa.

Similarly, Gunnarsson et al. (2001) show that upgrading skills at a given level of ICT has a much stronger growth–enhancing effect than increasing ICT investments at a given human capital structure. Workers with higher education will be more efficient and produce better quality products and services. In fact, higher technical efficiency scores indicate efficient utilization and management of resources, materials and inputs necessary for the production of goods and services. Generally, it refers to the additional output generated through enhancements in efficiency arising from advancements in worker education, skills and expertise, acquisition of efficient management techniques and know-how, introduction of new technology and innovation or upgrading of existing technology and enhancement in ICT.

In most developing countries, ICT infrastructure and services have been owned and operated mainly by government, typically through a postal, telegraph and telephone administration (PTT). The classical argument favoring the PTT have been economic, social and political (Straubhaar, 1995; Petrazzini, 1995; Frieden, 1996). In these countries telecommunication has been viewed as a natural monopoly. As a vital national infrastructure for integrating and managing a country, particularly in times of crisis, telecommunication has been viewed as a key element of national military and economic security, too important to be left in private hands, whether domestic or foreign (Urey, 1995; Yildizoghlu, 1996).

However, Iran recently has been planning to open its telecommunications sector to foreign operators in order to meet high public demand for telephone lines and Internet access. The government is preparing legal changes to pave the way for foreign firms to enter the market. The country is now taking first steps towards privatization and establishing regulatory policy which would allow the entry of the private sector. Foreign operators will be invited to provide mobile and fixed-line communications as well as internet access to Iran's 62 million consumers (http://news.bbc.co.uk/1/hi/business/1654747.stm).

Of specific note has been the results of the privatization policies of the Ministry. By way of example, since ceding activities of ISP's to the private sector, the number of ISP's has grown by %500 whereas price have been reduced to one-tenth of their original prices. As Iran is exploring the prospect of allowing the private sector to purchase 3G licenses, the valuation of a 3G license in the country has been estimated to be in the vicinity of US $28 billion, the highest valuation of any country in the Middle East. Also, the numbers of ISP's and E-commerce sites are continuing to grow (http://www.shahkooh.com/edifact.html, 19th AFACT Meeting, Jakarta, 2001). South Korea, often cited as the Broadband global leader, is sharing some of their technical savvy with Iran. The country will be providing some 100,000 Broadband connections to 20 different Iranian cities in a deal worth US$40 million (http://www.broadbandreports.com/shownews/53894).

6. Concluding Remarks and Implications

This paper extends the existing evidence on the debate of the impact of ICT on productivity using data from the entire Iranian manufacturing sector over the period 1993–1999. Estimates of efficiency at industry level using panel data confirm the result of a positive and significant impact of ICT on productive efficiency found by the most recent literature in the context of developed and a few middle-income developing countries. This paper makes a number of contributions to our understanding of ICT impact on productivity. First, although ICT and productivity is not a new area of research, there has been little research dedicated to investigate the ICT impact in developing countries. As such, this paper adds an international dimension to the investigation, extending beyond the context of industrialized countries since developing countries may have very different economic and regulatory environments (Dewan et al., 2000; Jarvenpaa et al., 1998).

Second, the current paper provides empirical evidence of the existence of positive and significant ICT impact at the industry level. As Crowston et al. (2004) suggest, very little IS research has been conducted at the industry level. Most IS research focuses on the individual and organizational levels of analysis. Hence, they propose a research agenda for studying ICT and industries. They suggest three research perspectives for studying ICT and industries: an economic perspective, an institutional-legal perspective, and a socio-cultural perspective. Just as IS research that addresses these aspects at the organizational level has grown in recent years and contributed to our understanding of IS, so they argue that a similar broadening, as well as more studies, are needed at the industry level of analysis.

On the other hand, we have employed more recent panel data and more improved econometric tools; as modeling and measurement issues have been considered the heart of ICT productivity paradox problem. Not many studies have considered economic performance measure like technical efficiency of the production process in the area of the ICT. Larger samples comprising of panel data can improve the accuracy of the results by controlling for industry specific effects.

Human capital (educated population) and increasingly ICT capital (by government) are probably two determining factors in gaining the positive payoffs from ICT investments in Iran based on capital-skill complementarity hypothesis. Therefore, an important policy implication for developing countries is, increased use of ICT should be accompanied by skill upgrading of the human capital, otherwise there would be little return from the ICT investments in these countries. In other words, ICT investment can be more effective in growth if accompanied by better organization and management in government sector along with more private sector participation in the economy. Although the relationship between ICT and productivity in developing countries seems to be confusing and needs further investigation, model limitations or the low levels of human capital skill might be responsible for the apparent results.

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