ICT Impact on the Labor Productivity in the Iranian Manufacturing Industries; a Multilevel Analysis

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Abstract

It is now evident in the literature that the information and communication technology (ICT) has a positive and significant impact on the productivity and economic growth. Most studies in this area, however, are limited to the developed countries. Given different regulations and economic conditions, and also an increasing trend in allocating resources to ICT in developing countries, it is important to examine the impact of ICT spending in developing countries on the productivity and growth.

In this study, we search for an empirical relationship between ICT spending and labor productivity across the Iranian manufacturing industries. We use the survey data on the four-digit large manufacturing industries for the period 2000-2001. In order to control for the heterogeneity among different industry groups, we use the multilevel model. Our results show that the net effect of the ICT on the labor productivity is positive and significant, but not as high as what has been found in the developed countries.

Keywords: ICT, Manufacturing Industries, Iran, Multilevel Model, Labor Productivity.

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I- Introduction

In the 1980s and the 1990s, many economies in the world, and in particular developed countries, made enormous investment on the Information and Communication Technology (ICT) and also enjoyed a high economic growth for a relatively long period. Economists have been since trying to explain the nexus between ICT and the economic growth using various methodologies, techniques, and data sets. The early work on this issue in the 1980s and the early 1990s found a surprisingly negative or insignificant relationship between the ICT investment and the total factor productivity, hence an ICT puzzle [Roach (1989), Brynjolfsson & Yung (1996).] But, further investigations in the 1990s show a positive relationship between the ICT spending and the economic performance.

Various explanations for the ICT puzzle have been provided in the literature, including the delayed effects on productivity of the new technology, requirements of complementary infrastructure and inputs, and the network externalities. The limited data availability on the ICT investment, measurement errors due to rapid price and quality changes, poor measurement of output in the ICT-intensive service industry, along with the use of simple bivariate correlations between ICT and the productivity could also help explain the puzzle. Using richer data sets and more complicated quantitative methods and controlling for the various factors affecting the productivity, the more recent work support the contribution of the ICT investment to the productivity growth at both micro and macro levels. In fact, some studies suggest that there are *excess returns* on the ICT investment due to higher risk or higher depreciation of the ICT capital [Lichtenberg (1995), Brynjolfsson & Yung (1996), Jorgenson and Stiroh (2000).]

These studies, however, have mainly used the data from the U. S. or the other developed economies [Mun and Nadiri (2002), Becchetti et al (1993), Siegel and Griliches (1992), Melville (2001), Nishimura et al (2002)]. Despite the fact that ICT has now spread worldwide, only few studies have been conducted to examine the effect of this new technology in the less developed countries (LDCs). For instance, Madden and Savage (1998) study the impact of the telecommunication infrastructure investment on the Central and Eastern European economic growth and find a two-way causality between them. Lee and Khatri (2003) report a significant positive contribution of ICT capital to the total factor productivity among six Asian countries. Aochamub et al. (2002) find a positive effect of the telecommunication investment on economic growth in Namibia. Dewan and Kraemer (1998) and Pohjola (2000) also find positive relationship between the ICT investment and the economic growth in developed countries, but not a significant one in the LDCs. More recently, using the state space model, Moshiri and Jahangard (2004) show a positive relationship between the ICT spending and economic growth in Iran, and using the stochastic frontier production function method, Gholami, Moshiri, and Lee (2004) report a positive relationship between the ICT spending and the efficiency in the Iranian manufacturing industries over the period 1993-1999.

Obviously the question still remains as whether the ICT investment in developing countries have the same positive effects on the productivity as it does in the case of the most developed countries. The growth effect of ICT seems to be higher in the developing countries than that in the developed countries, as it would speed up the improvement in the already low state of the technology in all areas of the economy leading to a faster convergence process. However, the ICT investment requires certain complementary infrastructure and inputs, such as skilled labor, before its effects on the productivity are fully realized. In fact, it is the lack of the latter that justifies the negative impact of the ICT investment, in particular the hardware, on the productivity in some even advanced economies like Italy [Becchetti et al (2003).]

More empirical studies are needed before we make any conclusion about the relationship between ICT and productivity in developing countries. In this paper, we extend the literature of the relationship between ICT and productivity in developing countries by using the firm-level data on the Iranian manufacturing industries and applying a multivariate estimation model, which would capture the complexity of the behavior and the heterogeneity among the firms. The data are at four-digit level ISIC codes for the period 2001-2002. The list of two-digit manufacturing industries is presented in Table 1. The rest of the paper is organized as follows. In section 2, the labor productivity and the ICT spending in the Iranian manufacturing industries are discussed. In section 3, some theoretical discussion will be presented followed by a brief introduction of the multilevel modeling technique in section 4. The data description and the estimation results will be presented in section 5 and the concluding remarks in section 6.

II- Labor Productivity and ICT Spending in the Iranian Manufacturing Industries

Manufacturing sector is not usually the most ICT-intensive sector in the economy, and therefore, the study results on the ICT and productivity relationship cannot be easily generalized to the all economy. However, one advantage of using the manufacturing industries data is that the measurement of output and productivity is much more precise in this sector than other industries such as services, trade, and financial sectors. In this section, we briefly review the data on major variables used to investigate the productivity effect of ICT.

Labor Productivity

The labor productivity, defined as the ratio of the firm's value added to its number of workers, in the Iranian manufacturing industries was on average about $4,288 in 1995 (Figure 1). The productivity increased to $6,513 in 2001. These figures are equivalent to about $12 per day and $18 per day, respectively.

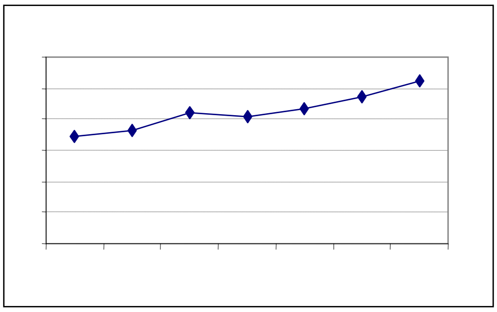

Figure 1: Labor Productivity in the Iranian Manufacturing Industries, 1995-2001 (Million Rials)

Source: Statistical Centre of Iran, Large Manufacturing Industries Survey (2001) and authors calculations.

Although the average labor productivity in the manufacturing industries is relatively low, it varies considerably across the industry with the highest productivity in the coke, refined petroleum products and nuclear fuel, and the lowest in the wearing apparel, dressing and dyeing of fur manufacturing. The cost index, defined as an inverse of the labor productivity, can be used to examine the technological change in a firm [Jones and Engerman (1996)]. A reduction in the cost index would indicate that the labor cost is lower, and therefore, its productivity is higher. The cost index in the Iranian manufacturing industries on average decreased from 29.2 in 2000 to 19.2 in 2001, indicating a significant improvement in the productivity of labor. However, there is a large variation in the trend among the manufacturing industries. It has been decreasing very fast in manufacturing industries such as coke and refined petroleum products, but increasing in textile.

Decomposition of the cost index based on the workers education level shows that the cost index for labor with higher education has been increasing for the past decade, mainly because of a fast increase in employment of higher educated labor. Specifically, the cost index for labor with higher education was 2.2 in 1995, but increased to 3.5 in 2001 (Figure 2). It is lowest in the manufacturing industries such as coke, refined petroleum products and nuclear fuel, and motor vehicles, and highest in the manufacturing industries such as machinery and equipment, electrical machinery and apparatus.

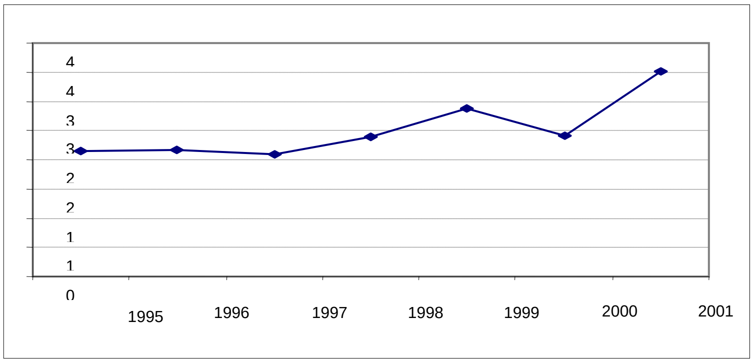

Figure 2: The Ratio of Labor with Higher Education to Value Added for Iranian the Manufacturing Industries, 1995-2001

Source: Statistical Centre of Iran, Large Manufacturing Industries Survey (2001) and authors calculations.

b- ICT Spending

The data on ICT is not usually readily available, but two indexes have been suggested to measure the ICT use in the firm. The first is the ratio of the telephone and communication spending to the firm's value added, and the second is the ratio of spending on software to the firm's value added [Becchetti, Bedoya, and Paganetto (1993), Brynjolfsson (1995, 1996)]. The telephone and communication ratio in general increased in 1997-1998, but decreased thereafter reaching its pre 1997 level, that is, 0.23 percent (Figure 3). The ratio has increased in most industries except for tanning and dressing of leather, manufacturing of luggage, handbags, saddlery, harness and footwear, coke, refined petroleum products and nuclear fuel, fabricated metal products, and other transport equipments. The ratio is also higher among manufacturing industries such as publishing, printing, and reproduction of recorded media, clothing, medical, precision and optical Instruments, watches and clocks, electrical machinery and apparatus.

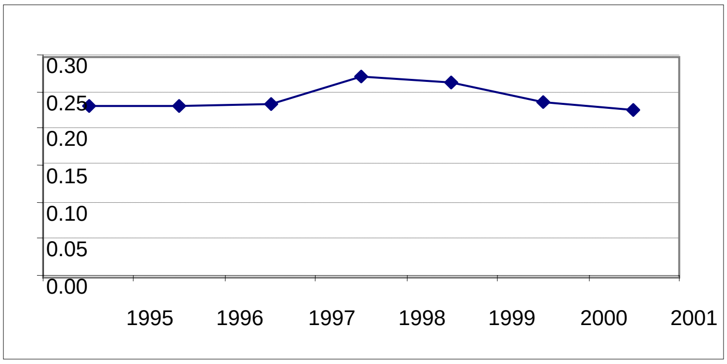

Figure 3: The Ratio of ICT Spending to Value Added for the Iranian Manufacturing Industries, 1995-2001

Source: Statistical Centre of Iran, Large Manufacturing Industries Survey (2001) and authors calculations.

The second index, the software ratio, shows a dramatic increase from 0.075 percent in 2000 to 0.33 percent in 2001, which indicates a significant shift in using computer software among the manufacturing industries (Table 1). The change, however, is not universal. In fact, the ratio in some manufacturing; such as paper and paper products, wood and wood products, and non-metallic mineral products has decreased, indicating that spending on

Table 1: Cost Index, and the ICT Ratios for the Two-Digit Manufacturing Industries in Iran

Industry	ISIC Codes	Cost Index[1]	ICT ratio[2]	Software Spending ratio	
			2001	2000	2001
Manufacture of food products and beverages	15	3.7	0.30	0.09	0.11
Manufacture of tobacco products	16	3.5	0.18	0.00	0.05
Manufacture of textiles	17	3.1	0.38	0.05	0.05
Manufacture of wearing apparel; dressing and dyeing of fur	18	2.1	.050	0.03	0.06

Tanning and dressing of leather ; manufacture of luggage, handbags, saddler, harness, and footwear	19	2.1	0.40	0.03	0.00
Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	20	4.1	0.39	0.16	0.01
Manufacture of paper and paper products	21	4.0	0.38	0.06	0.01
Publishing, printing and reproduction of recorded media	22	4.1	0.47	0.18	0.13
Manufacture of coke, refined petroleum products and nuclear fuel	23	1.1	0.05	0.01	0.00
Manufacture of chemicals and chemical products	24	2.1	0.18	0.03	0.04
Manufacture of rubber and plastic products	25	4.0	0.32	0.14	0.14
Manufacture of other non – metallic mineral products	26	2.3	0.22	0.50	0.00
Manufacture of basic metals	27	2.5	0.18	0.10	0.01
Manufacture of fabricated metal products, except machinery and equipment	28	10	0.30	0.16	0.02
Manufacture of machinery and equipment n.e.c.	29	13.5	0.40	0.08	0.46
Manufacture of office, accounting and computing machinery	30	7.6	0.40	0.01	0.01
Manufacture of electrical machinery and apparatus n.e.c.	31	11.4	0.40	0.18	0.02
Manufacture of radio, television and communication equipment and apparatus	32	2.9	0.31	0.01	0.01
Manufacture of medical, precision and optical instruments, watches and clocks	33	6.1	0.43	0.08	0.01
Manufacture of motor vehicles, trailers and semi- trailers	34	2.0	0.06	0.10	1.01
Manufacture of other transport equipment	35	2.7	0.38	0.04	0.00
Manufacture of furniture; manufacturing n.e.c.	36	4.0	0.39	0.04	0.47

Source: Statistical Centre of Iran, Large Manufacturing Industries Survey (2001) and authors calculations.

1- Defined as the inverse of the labor (with higher education) productivity.

2- Defined as the ratio of the ICT to the value added, in person/billion Rials (~$125,000) other capitals has been more important than that on software. Overall, in 2001, the software spending has been higher among the manufacturing industries such as food products and beverages, printing and publishing and reproducing of recorded media, rubber and plastic products, machinery and equipment, and motor vehicles, and lower among the manufacturing industries such as tobacco products, leather, luggage and footwear, non-metallic minerals products in 2001.

To get a larger picture of the manufacturing industries condition in Iran, we classify them based on the type of technology they use. We apply the criteria used by Lall (2000) based on Pavit (1984) and OECD (1994). In this classification, the technologies employed in the manufacturing industries can be categorized into four types: resource based, low technology, medium technology, and high technology. The resource based products are simple and labor intensive, such as food and leather processing. The low technology products employ stable technologies that are embodied in capital. They are homogeneous products with low economies of scale and usually require simple skill labor. Textile, clothing, and shoes are examples of the manufacturing industries with the low technology. The medium technology products use complex technologies, moderately high levels of R&D, and high-skilled labor. Motor vehicles, chemical and basic metal industries can fit in this category. And finally, the high technology products use advanced and rapid changing technologies with a very high R&D spending and a focus on product design. The high technology also requires very high-skilled labor and strong interaction among firms and the academic and research institutions. The electronic products can be categorized as high technology products.

Although not comprehensive, the classification above generates a fairly large picture of the state of technology in the manufacturing industries in an economy. Based on this classification, 48 percent of the manufacturing industries products in Iran are the resource based technology. About 19 percent of the products can be categorized as low technology products, 31 percent medium technology products, and 2 percent high technology products. Overall, about 67 percent of the manufacturing industries products in Iran are the resource based or low technology products.

II- ICT and Productivity: Some Theoretical Discussion

In general, ICT has both demand and supply effects. ICT can enter the consumer's utility function along with the consumption of the other goods, and also the production function along with the other inputs [Quah, 2003]. In this paper, since our concern is the productivity effects of the ICT, we would focus on the supply side.

ICT can enhance the productivity of firms through an improvement in the capacity utilization and the economies of scope. The investment in new software also increases the productivity of labor leading to higher demand for skilled labor [Becchetti et al (2003).] The ICT related productivity improvement might come from three possible sources. First, the level of capital per worker would increase, or "capital deepening." Second, the quality of the inputs, including labor with higher education, would increase. And third, the multi factor productivity would rise, implying the use of improved technology which would enable the firm to produce more or better quality outputs using the same amount of inputs.

The ICT capital deepening is similar to the non-ICT capital accumulation process in the standard neoclassical model presented below.

$$\dot{y} = \sum_{j \in X} s_j \dot{x}_j + \varepsilon \qquad (1)$$

Where $\dot{y}_{it}$ represent output growth rate, $\dot{x}$ input (including ICT) growth , s input elasticities of output, and ε residuals. In this set up, we can examine the effect of ICT capital on the labor productivity growth by estimating the ICT elasticity of output in tion (1). According to Solow (1957), assuming competitive input markets, where input prices are l to marginal products, and input exhaustion, i.e., input factors receive all revenue, each input cost share is l to its output elasticity at the equilibrium. That is,

$$s_j = \frac{\partial y}{\partial x_j} \frac{x_j}{y} = \frac{p_j}{p} \frac{x_j}{y}$$

Where p_j is the rental price of input j and p the output price. In the case of ICT, rapid technological change leads to falling ICT product prices, and therefore, an increase in the ICT investment by firms in the form of input substitution or new investment.

The return on the ICT investment is shown to be higher than the traditional returns from the non-ICT capital used in the production. One possible explanation is that the expected returns on new and rapidly growing technology with little experience in management and market would be more uncertain than returns on the alternative investments, and therefore, it requires a risk premium. Furthermore, due to the rapid technological change, many newly developed ICT capital and software have a short life time leading to a higher rental cost of ICT relative to other inputs and raising the ICT input share. This implies that the ICT capital must have large marginal products to cover the high rental cost [Stiroh (2002)].

The total factor productivity effect of ICT can be measured by an estimation of ε as the Solow residual. In this set up, the implicit production function, with Hicks neutral technology, is used to estimate the residuals which represent the effects of factors other than the observed inputs that are included explicitly in tion 2.

$$\varepsilon = \dot{y} - \sum_{j \in X} s_{ji} \dot{x}_j \qquad (2)$$

However, the total factor productivity effect of ICT goes beyond the neoclassical models of output growth. If we include ICT as an input factor in the production function, then there will be no direct relationship between the ICT capital and the total factor productivity. There are, however, some explanations for how these two variables might be related, such as the production and network externalities [Brynjolfsson and Kemerer (1996), Griliches and Siegel (1991)], measurement errors [Griliches (1995), Diewert and Fox (1999)], omitted variables [Brynjolfsson and Hitt (2000)], and imperfect competition [Basu and Fernald (1997)]. If the neoclassical assumptions fail, the ICT effect will be represented in both the ICT input share and the total factor productivity. But the theoretical discussion and empirical results on the total factor productivity effects of the ICT are far from conclusive [Stiroh (2002)].

ICT is also known as a General Purpose Technology (GPT), such as steam and electricity, which grows fast and spreads widely in different economic activities. The GPTs affect the economic growth in three phases:

minimal impact, acceleration, and fading away. The initial impact of a new technology, such as ICT, on the economy would be very low and it might take several decades for its potentials to be fully realized. Only when the use of new technology becomes profitable and its great benefits are realized by all other sectors in the economy, it will then be widely used and its impact on the economic growth is accelerated. In the final phase, the scope of the technology is exhausted, and therefore, its impact on productivity and the economic growth will fade away. The long delayed expansion of the new technologies may partially be due to their spillover effects. If the new technology has a positive spillover, it will be under allocated in a competitive market system, since the social returns will exceed the private returns. This is particularly true, where there is no or poor public regulation to protect the property rights of entrepreneurs and innovators, who would take the risk of using the new technology to produce novel goods and services. Applying this argument to Economic development may help us explain why new technologies are not usually developed in less developed economies, where there exists no clear property right, and also why it took about two decades before the potentials of ICT were realized. The spillover effect of ICT also implies that government policy can be effective in reducing the long delay phase of new technology and in bringing about efficiency to the market.

III- The Multilevel Model

The multilevel modeling approach is based on the fact that most economic variables are related with each other in more than one level. For instance, the firms' outputs and inputs are related with each other in dimensions such as time, region, type of activities, market structure, and other economic, social and institutional levels. The initial relationship between the variables can be considered at level 1, and the relationship among other factors at higher levels. The multilevel models capture the effects of various levels on the initial relationship by allowing the coefficients to vary with the levels [Goldstien (1995), Naderi (2001)].

Here, we present a two-level version of the multilevel model, and refer the interested readers to Goldstein (1995) for the more general case. A two-level model can be written as follows.

$$
\begin{aligned}
&y_{ij} = \beta_{0j} + \beta_{1j}x_{1ij} + \sum_{h=2}^{p}\beta_h x_{hij} + \varepsilon_{0ij} \\
&where \\
&\beta_{0j} = \beta_0 + u_{0j} \\
&\beta_{1j} = \beta_1 + u_{1j} \\
&and\ E(u_{0j}) = E(u_{1j}) = 0, \\
&\text{var}(u_{0j}) = \sigma_{u0}^2,\quad \text{var}(u_{1j}) = \sigma_{u1}^2,\quad \text{cov}(u_{0j}, u_{1j}) = \sigma_{u01}
\end{aligned}
\tag{3}
$$

where i and j refer to the level 1 and level 2 units, respectively. In this simple model, the relationship between y and a p-dimensional vector X is considered at two levels, and therefore, there are two corresponding groups of error terms: ε_{0ij}, and u . The first error term with zero mean and variance $\sigma_{\varepsilon 0}^2$ is the level 1 error term, and the other two, which randomize the coefficients, represent the level 2 error terms. Substituting $\beta's$ in the original tion, it can be written as follows.

$$
y_{ij} = \beta_0 + \beta_1 x_{1ij} + \sum_{h=2}^{p}\beta_h x_{hij} + (u_{0j} + u_{1j}x_{1ij} + \varepsilon_{0ij}) \tag{4}
$$

The terms including the intercept and the explanatory variables (X) are called fixed part, and the terms inside the bracket random part. In total, there are p+5 coefficients to estimate: p+1 of β's, three variances (σ_{u0}^2, σ_{u1}^2, $\sigma_{\varepsilon 0}^2$), and one level 2 covariance (σ_{u01}). The variance-covariance matrix of the regression above is as follows.

$$
\begin{aligned}
&V = X_j \Omega_2 X_j^T + \begin{bmatrix} \Omega_1 & \\ & \Omega_1 \end{bmatrix} \\
&where \\
&X_j = \begin{bmatrix} 1 & x_{1j} \\ 1 & x_{2j} \end{bmatrix},\ \Omega_2 = \begin{bmatrix} \sigma_{u0}^2 & \sigma_{u01} \\ \sigma_{u01} & \sigma_{u1}^2 \end{bmatrix},\ and\ \Omega_1 = \sigma_{\varepsilon 0}^2
\end{aligned}
\tag{5}
$$

The multilevel models are more appropriate when there is heterogeneity among the units in different levels or hierarchy structure in the data. We can test for existence of such structures in the data by using an intra-unit correlation statistics. For the two-level model, with only intercept being randomized, it is defined as follows.

$$\rho = \frac{\sigma_{u0}^2}{\sigma_{u0}^2 + \sigma_{\varepsilon 0}^2} \tag{6}$$

where $\sigma_{u0}^2 = \text{cov}(u_{0j} + \varepsilon_{0i_1 j}, u_{0j} + \varepsilon_{0i_2 j})$. Here, we have assumed the model includes only two random parameters σ_{u0}^2 and $\sigma_{\varepsilon 0}^2$, and the level 1 residuals are independent. The intra-unit correlation (ρ) measures the proportion of the total variance, which is between the level 2 units. If the residuals in the higher level are not independent, ρ will not be zero, and therefore, the higher level residuals should be included in the model along with the original (level 1) residuals. With non-zero ρ, the use of traditional estimation methods such as OLS would be inappropriate, leading to incorrect inferences.

To estimate the multilevel models, we can use Generalized Least Square (GLS) or maximum likelihood estimation methods. If the parameters of the variance-covariance matrix (V) are not known, we can apply the Iterated GLS method [Goldstein (1995)].

IV - Estimation Results

The Data

The data on output and inputs for the manufacturing industry in Iran were obtained from the Manufacturing Industry Survey conducted by the Statistics Center of Iran. The survey collects the detailed data on the four-digit manufacturing industries with 10 or more workers. We use the data for the period 2000-2001, since the ICT data for four-digit manufacturing industries are only available for this period. All the monetary variables with current prices are converted to the 1997 prices using the Producers Price Index published by the Central Bank of Iran. Since there is no data available on capital stock for the four-digit manufacturing industries, we estimate it using the 1972 capital stock data, which is available from the Ministry of Economics and Finance, for the industries in nine aggregate groups. The estimation procedure is explained in the appendix.

Due to lake of data, we have used the computer software investment as a proxy for the ICT capital[1]. Since there is no data on the initial ICT capital and also there is no long enough time series data to estimate it, we have approximated the ICT capital in 2000 by multiplying the computer investment share of the total investment by the total capital stock in each four-digit manufacturing industry. The ICT capita stock in 2001 was then estimated by the capital stock adjustment rule.

In total, there are 264 observations of the manufacturing industries outputs and inputs for 132 types of the manufacturing industries. The former are assumed as the level-1 unit observations and the latter level-2 units observations.

Estimation

We estimate the effect of ICT on the labor productivity using the multilevel model presented in the previous section. The underlying reason for using the multilevel model is the assumption that the effects of ICT on the labor productivity are not the same among manufacturing industries. In other words, the initial relationship between the ICT and the labor productivity may be influenced by the higher level units, i.e., the manufacturing industries. For example, the ICT is expected to have a higher effect on the labor productivity in manufacturing industries such as electronic computation devices, computer hardware, and medical equipments compared with those like shoes and leather products, because they employ different types of technologies and also they have different levels of ICT complimentary factors, such as high skilled labor. In this paper, we use a two-level model in which time is the first level, and the manufacturing industry is the second level. In this setup we would be able to decompose the

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1- I n general an investment or capital hardware, software, communication and services are used as a proxy for the ICT investment in the literature.

variance of the labor productivity among the units in two different levels: time and the type of activities.

As discussed in section IV, the multilevel models are more appropriate when applied to the data with a hierarchical structure, where the covariance among observations in the higher level is not zero, and the variance of the error terms is not constant. To test for the presence of the hierarchical data structure and the heterogeneity among the units in the second level, we estimate the intra-unit correlation statistics, tion (4), as follows.

$$\hat{\rho} = \frac{287.2}{287.2 + 193.1} = 0.402$$

The non-zero intra-unit correlation leads to a rejection of the hypothesis of identical coefficients for all types of activities, indicating that about 40 percent of changes in the labor productivity is due to the differences among the manufacturing industries, i.e., the level 2 units. Therefore, we would gain efficiency if we use the multilevel model rather than the traditional uni-level model.

The tion we estimate is based on the two-level model, presented by (2), as follows.

$$y_{it} = \beta_0 + \beta_1 (ict)_{it} + \beta_2 k_{it} + (u_{0t} + \varepsilon_{0it}) \quad (7)$$

where y_{it} is the labor productivity of the manufacturing industry i at time t, defined as the output-labor ratio, ict is the ICT capital per worker approximated by the software spending per worker, k is the non-ICT capital per worker. The two error terms, u and ε, represent the level 2 (manufacturing industries) and the level 1 (the original observations) error terms, respectively.

We use Lisrel 8.54 software and the maximum likelihood method to estimate the effect of the ICT on the labor productivity among different manufacturing industries. The results are reported in Table 2.

Table 2 : The Multilevel Model Estimation Results for Labor Productivity in the Iranian Manufacturing Industries (tion 5)

Coefficients	Fixed		Coefficients	Random	
	Estimation	Z-Value		Estimation	Z-Value
β_0	2.11	0.94	σ_{11}^2	287.18	8.07
k	0.55	23.9	σ_{22}^2	193.14	4.26
ict	0.15	1.8			
-2 log (likelihood) = 2338.2					

Source: Authors Estimates

As the results in Table 2 indicate, ICT has a positive and significant impact on the labor productivity. More specifically, when the ICT capital increases by one unit, the labor productivity would increase by 0.15 units. This effect is gross, that is, it may be influenced by the effect of the non-ICT capital on the labor productivity. To estimate the net effect of the ICT capital on the labor productivity, we follow the three-step estimation process in the partial regression method described below. In step one, the labor productivity is regressed on the non-ICT capital per worker. The residual of the regression represents the impact of variables other than non-ICT capital per worker on the labor productivity. In step two, the ICT capital per worker is regressed on the non-ICT capital per worker. The residuals of this regression represent the impacts on the ICT capital of factors other than non-ICT capital. And finally, in step three, the residuals from step one regression are regressed on the residuals from step two regressions. The slope of this regression represents the net effect of the ICT capital on the labor productivity. The results of the three regressions are reported in Table 3.

Table 3: The Estimation Results for Labor Productivity in the Iranian Manufacturing Industries Using the Three Steps Partial Regression Model

Step I*	Step II	Step III
$y_{it} = \alpha_0 + \alpha_1 k_{it} + \xi_{it}$	$ict_{it} = \delta_0 + \delta_1 k_{it} + \eta_{it}$	$\xi_{it} = \varphi_o + \varphi_1 \eta_{it} + \zeta_{it}$

Coefficient	***Estimate***	***Z-Value***	***Coefficient***	***Estimate***	***Z-Value***	***Coefficient***	***Estimate***	***Z-Value***
Intercept	2.8	1.26	Intercept	4.17	3.12	Intercept	0.0005	0.0003
k	0.55	23.9	k	-0.02	-1.5	Slope	0.15	1.80
σ_{11}^2	288.19	35.7	σ_{11}^2	226.82	8.09	σ_{11}^2	286.57	8.07
σ_{22}^2	199.77	4.3	σ_{22}^2	-3.86	-0.2	σ_{22}^2	194.14	4.28
-2 log (Likelihood) = 2341.4			-2 log (Likelihood) = 2160.19			-2 log (Likelihood) = 2338.2		

* Step I and II are the regressions of labor productivity (y) on capital (k), and k on ict, respectively. Step III is the regression of the step I residuals on the step II residuals. All variables are in per capital terms. The models are two-level models with intercept being randomized. The variances refer to the two error terms representing the two levels assumed in the model.

Source: Authors Estimates

As the results in Table 3 show, the non-ICT capital has positive effect on the labor productivity, and ICT capital has negative, but insignificant, effect on the non-ICT capital, indicating that these two capitals are not complementary inputs. The net effect of the ICT capital on the labor productivity, the slope coefficient in step III regression, is positive and similar to the original regression results presented in Table 2.

Two major observations can be made here. First, the investment in the physical capital and the ICT capital in the Iranian manufacturing industries are not strongly correlated with each other. In other words, the manufacturing industries have not yet reached the stage at which the ICT capital and the physical capital are complementary inputs. This may be an indication of the use of older capital or ICT- independent capitals in the manufacturing industries during this period in Iran. The second observation is that the impact of the ICT capital on the labor productivity is less (about 1/3) than that of the non-ICT capital. This may seem puzzling at first sight. The small size of the ICT capital is to generate a larger marginal product, which is reflected by the coefficients. However, the fact that the ICT capital is not supplemented enough by the required complementary factors such as network infrastructure, human capital, legal institution, and government support would reduce its impact on productivity .The other possible explanation is that since the software productivity is partly related to the network; the more firms and people use the software ,i.e., the more realized its benefits would be; the low level of ICT investment and therefore poor networking may have led to a situation in which the ICT capital is underemployed. Finally, our proxy for the ICT capital may have underestimated the ICT capital.

II- Conclusion

The results suggest that ICT has a positive and significant impact on the labor productivity in the Iranian manufacturing industries during 2000-2001. This result is obtained from a multilevel model using the data on the four-digit manufacturing industries with 10 or more workers. We set up a model at two different levels. The first level is the initial relationship among the labor productivity and its explanatory factors such as the capital stock per worker and the ICT capital per worker. The second level is the manufacturing industry. Since the level 1 relationship might have been affected by the heterogeneity among the manufacturing industries (level 2), the use of the multilevel model would produce more efficient results.

The estimation results show that one unit change in the ICT capital per worker, approximated by spending on software, could increase the labor productivity by 0.15 units. More specifically, if the ICT per worker rises by $125, the labor productivity would increase by $18.8 annually or $0.05 per day. The result is almost the same when we use the partial regression model, which isolates the effects of the other variables on the ICT-labor productivity relationship. Although the ICT impact on the labor productivity is positive and significant, it is not as high as the non-ICT capital effect, and as high as the impact reported for the developed countries.

Given the positive effects of the ICT on the productivity, the ICT provides opportunities for developing countries such as Iran to increase their competitiveness, and therefore, speed up their convergence rate. As the recent experience of the developed countries show, the ICT effect on the economic performance can be fully realized if it is supported by the required infrastructure and other complimentary inputs such as skilled labor. More stringent regulations on the intellectual property rights, reform of education system to become more compatible with the requirements of the new economy, along with the financial incentives would pave the way to expand the ICT sector and its productive use in the economy. Finally, since ICT can be developed more rapidly through networking, the quick expansion of information and telecommunication networks would be imperative to full utilization of the technology, and therefore, to its impact on the productivity and economic growth.

Appendix

Estimation of Capital Stock for the Four-digit Level Manufacturing Industries

To estimate the production function, we need time series information on capital stock (K). Since the data for K is not available, we estimate it using the data for nine manufacturing industries groups in 1972, which is available from the Ministry of Economics and Finance. The process is as follows[1].

1- We use the following rule of capital movement to obtain capital stock for the period 1973-2001.

$$K_{t,i} = (1-\delta)K_{1972,i} + I_{t,i}, \quad i = 1,...,9, \; and \; t = 1973,...,2001$$

Assuming a range of values for the depreciation rate ($0.01 < \delta < 0.2$), we generate different series of K.[2]

2- Using Ks obtained above, we estimate different production functions. We then choose the best production function based on the significance of the coefficients and the coefficient of determination criteria. The series of K corresponding to this production function is our best estimate of K for the nine manufacturing industries groups.

3- then convert Ks obtained above to Ks for the four-digit level manufacturing industries using the following formula.

$$K_{i,j} = (K/Y)_i Y_{i,j} \quad i = 1,...,9$$

1- We make two adjustments to the original data. First, since the data covers all manufacturing industries, we adjust it for the number of workers to obtain the data for the manufacturing industries with 10 and more workers. Second, we adjust the data for the price change to get the constant price values.

2- The 1980-88 war damage, which is estimated by the Management and Planning Organization, is also taken into account.

$(K/Y)_i$ is the capital-output ratio for group i, $K_{i,j}$ and $Y_{i,j}$ are the capital and output for the subgroups j of group i.

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