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Impact of ICT on the Productivity of the Firm:

Evidence from Turkish Manufacturing

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Abstract
This paper aims to explore the impact of Information and Communication Technologies (ICT) on labor productivity growth in Turkish manufacturing. This is the first attempt at exploring the impact of ICT on productivity in Turkish manufacturing at the firm level. The analysis is based on firm level data obtained from Turkish Statistical Institute (TURKSTAT) and covers the period from 2003 to 2010. The data used in the analysis includes all firms employing 19+ workers in Turkish manufacturing industry. Growth accounting results show that the contributions of conventional and ICT capital to value added growth are not significantly different from each other. On the other hand, results based both on static (fixed-effects) and dynamic panel data analysis highlight the positive influence on firms' productivity exerted by ICT capital. The findings show that the impact of ICT capital on productivity is larger by about 25% to 50% than that of conventional capital. Our findings imply that investing in ICT capital increases firm productivity by increasing the productivity of labor and also that convention growth accounting approaches may not be adequate to identify such linkages.

Keywords: Productivity, TFP, ICT, manufacturing industry, Turkey.

JEL Codes: D24, L60, O14.

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1. Introduction

Although economists disagree on many contemporary issues in economics, there is a strong consensus that the primary source of long run economic growth is productivity growth. The theoretical underpinnings of such a perspective have been bolstered by the empirical record of the twentieth century, which has witnessed remarkable productive increases not only in manufacturing but also in the other industries of the world's economies. The contribution of factor accumulation, especially capital, in this productivity increase was quite significant at least until the 1970s, as labor productivity was substantially enhanced via capital accumulation. Productivity growth in most of the developed world, however, has slowed since the 1970s, a time at which IT investment was accelerating worldwide. Observed Nobel Laureate Robert Solow (1987) in The New York Times (12 July 1987) a decade later, "*we could see the computer age everywhere but not in the productivity statistics*." The slowdown in US productivity growth in the mid 1970s and the widespread adoption of computers, whose price/cycle were dropping at exponential rates, were observed simultaneously (Van Reenen et al., 2006; Hulten, 2001). Productivity growth picked up again, especially in the 1990s, and since that time productivity levels have trended to levels that stand at record highs, both in manufacturing and in many other industries. This development has been mainly attributed to the production and widespread use of Information and Communication Technologies (ICT). There is a broad consensus of governmental agencies and academic researchers that widespread usage of ICT has had a profound impact on levels of productivity. Until the early and mid-1990's the role of Information and Communication Technologies (ICT) in productivity and growth was still open to debate, as the effects of the ICT revolution on growth were not yet fully visible or measurable. But by the end of the nineties, the academic literature was broadly in agreement on the importance of ICT for the U.S. growth resurgence observed from 1995 to 2000 (see for example; Jorgenson et al. , 2008; Oliner and Sichel, 1994; van Ark et al., 2008)[2].

Studies focusing on estimating productivity and quantifying the impact of ICT on productivity growth in the economies of the word are widespread. In Turkey, however, the studies examining the impact of ICT on both output and productivity are quite limited. The main purpose and novelty of this paper is to explore the impact of Information and Communication Technologies on output and productivity growth in Turkish manufacturing.

[2] Jorgenson et al. (2008) estimate that the share attributable to ICT in US growth performance went from 43% for the period 1971-1995 to 59% for the period 1995- 2000. The contribution from increased investment in ICT capital almost doubled (ICT capital deepening) and there was a more than twofold increase in TFP. For the post-2000 period, they found that ICTs accounted for about 38% of the US output growth.

This is very important as the extent of the impact of ICT utilization and production on firm's output and productivity growth in Turkish manufacturing is quite limited, even though the widespread usage of ICT at the firms operating in both manufacturing and in other industries is evident. Moreover, due to the increased economic importance of ICT in Turkey, proper measurement of its impact is crucial for effective policy making.

To address the puzzles raised by the existing evidence on ICT and productivity, we first use growth accounting methods to assess the differences between conventional and ICT capital in contributing to value added growth. We also apply an econometric methodology in estimating the production function and quantifying the impact of ICT capital on labor productivity. We estimate firm level production functions by means of panel data estimation methodologies applying both fixed-effects and Generalized Method of Moments (GMM) models. We evaluate the intensity of ICT and its impact of productivity using the Annual Industry and Service Statistics Database obtained from Turkish Statistical Institute (TURKSTAT). This database covers all Turkish manufacturing firms employing 19+ workers and 60% of the firms employing less than 19 workers and provides firm level information on many firm-specific variables for the period 2003 to 2010.

The paper is organized as follows: Section 2 surveys the theory and empirical literature on the relations between output growth, productivity and ICT. The next section introduces the data set used in exploring the impact of ICT on productivity and briefly puts forward the methodology used to calculate conventional and ICT capital stock. Section 4 first provides a brief statistical analysis where output growth is decomposed into the factor input contributions and then develops the econometric analysis and provides the findings on the impact of ICT on productivity in Turkish manufacturing industry. Finally, Section 5 concludes after a short discussion of the key results from this study and evaluates the policy implications.

2. Productivity and the Turkish ICT/Productivity Nexus

Productivity as a measure of the efficiency of production is defined as a ratio of output to inputs used in the production. *Labor productivity* defined as the ratio of output/value added to the number of workers or of hours worked is a commonly used partial measure of productivity. Widespread utilization of labor productivity is due in part by its ease of implementation, especially in developing countries where data collection protocols make total factor productivity measurement difficult to assess. Typically, establishment-level productivity studies assume output (usually measured as deflated sales or value added) to be a function of the inputs the firm employs and its productivity (Van Beveren, 2012). The measure of *Total factor productivity (TFP)*, also called *multi-factor productivity*, obtained as the residual in this functional relationship, on the other hand, is a measure of productivity that accounts for the output increase not caused by the factors of production. *TFP* reflects technological change or technological dynamism. *TFP* cannot be measured directly. It instead is a residual, often called the Solow residual, which accounts for effects in total output not caused by inputs.

The many methodologies available for productivity estimation are distinguished based on several criteria. A primary criterion involves the level of aggregation and whether the researcher is concerned with aggregate (countries/regions/industry) productivity, or productivity of micro units (firm/plant) (Del Gatto et al., 2011).

Aggregate studies can be further distinguished by the role *TFP* has in explaining growth dynamics and differences in economic performance across countries. This literature rests largely on the Solow growth theory, in which the pattern of productivity growth reflects technological progress, typically measured by the Solow residual. This *growth accounting* methodology has been used to estimate *TFP* at both aggregate and sector level and dates back to the 1950s (Abramovitz, 1956; Solow, 1957). Growth accounting provides a convenient way to decompose output growth into the growth of the factor inputs and total factor productivity (TFP) growth. In Solow's (1957) original contribution, only the inputs of labor and capital were considered. Subsequently, the role of human capital accumulation on output growth was recognized by a variety of authors (see for example, Mankiw et al., 1992).

An extension of the growth accounting methodology that has been suggested to improve traditional Solow residual estimates is the *level or development accounting decomposition* (Hall and Jones, 1999). This methodology focuses on the estimation of *TFP* levels instead of their growth rates. The development accounting decomposition aims at quantifying the relative contribution of factors of production and efficiency with which these factors are used in explaining cross-countries income differences (Del Gatto et al., 2011). Thus, the focus on *TFP* levels instead of rates of change is important in growth models where technology transfers represent the main engine for growth and convergence (Parente and Prescott, 1994).

Among aggregate studies, *growth regressions* offer up another alternative method to estimate *TFP*. Like growth accounting, these are extensions of the standard Solow growth model. However, they use a model-based approach that identifies a structural equation to estimate TFP levels from aggregate data (Islam, 1995; Caselli et al., 1996). Therefore, the advantage of growth regressions is that *TFP* is not estimated as a residual from an adjustment exercise. Moreover, this approach does not need to use data on the stocks of physical capital that are likely to be characterized by significant measurement errors.

Another alternative method to estimate *TFP* is to utilize *frontier models* wherein observed production units do not fully utilize their existing technology. These have been applied at both aggregate and individual level. In the presence of inefficiency, productivity measurement is affected and it will be relevant to provide evidence on the contribution of efficiency change to productivity change (Del Gatto et al., 2011). Generalizations that allow for the presence of time varying technical inefficiency in production are particularly valuable (see, for example, Cornwell, Schmidt, and Sickles, 1990). An appeal of frontier methods and one of the main reasons for their widespread adoption is their capability to diversify two main sources of productivity growth (Del Gatto et al., 2011:954). The first one, technological change, is assumed to expand the frontier of potential production while the second, technical efficiency change, reflects the capability of productive units to improve production with a set of given inputs and available technology. Empirical models that have been developed to estimate these sources of productivity change have been largely delineated into mathematical programming approach, in particular *data envelopment analysis (DEA)* and regression-based approaches that are subsumed in the broadly defined *stochastic frontier analysis (SFA)* literature. *DEA* attempts to overcome some of the specific weaknesses of the growth accounting approach such as a particular functional form for technology, particular assumptions on market structure, and the hypothesis that markets are perfect (Del Gatto et al., 2011). By enveloping the observed input–output combinations DEA attains an approximation of the production frontier (or "best-practice" frontier) and uses this to identify the contribution of technological change, technological catch-up and input accumulation to productivity growth (Del Gatto et al., 2011). *SFA* also assumes that firms cannot produce using the most efficient available technology models this shortfall from potential output using random shocks to represent the shortfall.

The interest in estimating individual (firm/plant) productivity gained importance due to the increasing availability of micro-level data and the development of a theoretical literature in which firms are assumed to be heterogeneous in terms of productivity. The main focus of this strand of literature is on the relationship between the productivity distribution of firms and the integration process (see for example, Bernard et al., 2003; Melitz and Ottaviano, 2008). The empirical literature dwells on understanding firm-level differences in performance, as well as in studying the determinants of these differences (see for example, Clerides et al., 1998; Pavcnik, 2002; Del Gatto et al., 2008). Studies in this field tend to rely on semi-parametric methods, based on proxy variables. These methods consider the main problems associated with estimating productivity at the firm level, namely simultaneity, selectivity and price dispersion. The key points of the semi-parametric methods are (*i*) the identification of a proxy variable, which is a function of the observed firm level TFP, and (*ii*) the definition of the conditions under which this function can be inverted in order to express TFP as a function of the proxy variable itself (Del Gatto et al., 2011:956). For example, Levinsohn and Petrin (2003) suggest using intermediate goods as a function of TFP and capital. This function is invertible provided that, with given capital, the utilization of intermediate goods increases with TFP growth. Olley and Pakes (1996) suggest using investment instead as a proxy in order to address the potential simultaneity bias in the production function estimates.

2. 1. Total Factor Productivity in Turkish Economy

Regarding Turkey, the determinants of growth and of the distribution of income across countries have been the focus of one strand of debate in the literature. The preferred method of analysis has been cross-country regressions that use information on individual countries over different time periods. For example, Çanga et al. (2007) analyze productivity growth in Turkey, EU-15 and Central and East European Countries over the period 1995-2006. They use the Malmquist productivity index to measure productivity and decompose productivity into two component measures, namely technical change and efficiency change. Determining EU-15 as the frontier for the period 1995-2006, they conclude that the Turkish economy has been suffering from a deceleration in TFP mostly as a result of the efficiency component since 2004.

There exist a number of studies that calculate TFP growth for the Turkish economy for the post 1960s period and examine its evolution for the aggregate economy and on a sectoral basis – see for example, Saygılı et al. (2001, 2005), Altuğ and Filiztekin (2006), or Ismihan and Metin-Özcan (2008). Ismihan and Metin-Özcan (2008) explore the sources of growth in the Turkish economy by performing growth accounting exercises over 1960-2004 as well as over the relevant sub-periods. They also analyze the role of a number of important policy-related factors, such as infrastructure investment, macroeconomic instability and imports, on total factor productivity by performing cointegration and impulse response analyses. Their results suggest that both TFP and capital accumulation were crucial sources of growth during the sample period. They also find that TFP is positively affected by imports and public infrastructure investment and negatively affected by macroeconomic instability.

A recent and extensive study by Altuğ et al. (2008) considers the sources of long-term economic growth for Turkey over the period 1880–2005. They employ the growth-accounting approach to decompose output growth into growth in the factors of production versus total factor productivity. Their study examines 125 years by decomposing into four periods, the nineteenth century until World War I, the period until 1950, the post- World War II era until 1973 and 1980, and the current era of globalization since. The authors use a two-sector model with an agricultural and non-agricultural sector and they also incorporated the impact of human capital in their estimation model. Their results point out that output growth in Turkey is primarily due to capital accumulation, not TFP growth.

Altuğ et al. (2008) conclude that during the entire 1950–2005 period, TFP growth is only slightly above 1 per cent per annum, in general, low for Turkey. Their findings are in line with the results of other studies that have conducted growth accounting exercises for Turkey. At the level of aggregate economy, Saygılı et al. (2001) find that TFP growth is equal to -0.29 percent for 1972–79 and 0.44 percent for 1980–2000. Altuğ and Filiztekin (2006), examine the behavior of the manufacturing sector for the period 1970–2000 and find that the contribution of TFP growth to output growth becomes positive only after 1980. The contribution of Altuğ et al. (2008) is to demonstrate that this result holds over much longer horizons and after taking into account the role of human capital and differences between the agricultural and non-agricultural sectors.

Another aggregate study that measures productivity in Turkey at the region level is Armağan et al. (2010). Accepting The Nomenclature of Territorial Units for Statistics (NUTS) regions in Turkey as a decision making unit, the study calculates the efficiency values of these regions, changes in the total factor productivity and technology for the 10-year period covering 1994–2003 for the agricultural sector. Methods of Data Envelopment Analysis and Malmquist Productivity Index are used in order to measure the crop production of NUTS regions. The authors conclude that there has been a decrease in the technical efficiency and total factor productivity in the regions, excluding the Western Marmara, the Aegean, the Mediterranean and The Eastern Black Sea Region, within the 10-year period analyzed.

Regarding the manufacturing sector in Turkey, there have been a considerable number of studies dealing with productivity (see for example, Krueger and Tuncer, 1982; Yıldırım, 1989; Aydoğuş, 1993; Gökçekuş, 1997; Önder and Lenger, 1993; Zaim and Taşkın, 1997). There is a list of studies that measure changes in TFP and in its components (technical efficiency) in the Turkish manufacturing industry at the regional level and for different ownership structures, namely public and private. These studies also differ in their methods of computing productivity.

For example, Taymaz and Saatçi (1997) estimate stochastic production frontiers for Turkish textile, motor vehicles, and cement industries for the 1987-92 period and conclude that there is a technical progress in the first two industries whereas there is no significant technical change in the cement industry. Another study, Zaim and Taşkın (2001), compares the performances of public and private manufacturing sectors in Turkey by using parametric and nonparametric production frontiers for panel data on the three-digit subsectors of the Turkish manufacturing industry for the 1974-95 period.

Önder et al. (2003a) measure technical efficiency and technical and total factor productivity changes by estimating a translog stochastic frontier production function for the Turkish manufacturing industry in selected provinces for the 1990-98 period. They find that a decline in the technical efficiency, but an improvement in technology, which together caused TFP change to fluctuate around a certain level. They also evaluated different performances of provinces in terms of efficiency by considering the effects of average firm size, the share of regional production, and the time period.

For the same period, Karadağ, et al. (2005) compute Malmquist productivity indices in the selected provinces using data envelopment analysis by decomposing into two components, namely efficiency change and technical change. They find that many of the provinces show improvement in TFP on average for the public sector, while in the private sector, only half of the provinces show growth in TFP. Moreover, they conclude that evidence of catching up can be observed only in the private sector. Their results also reveal that technical progress plays the main role in productivity growth.

Önder et al. (2003b) compare data envelopment analysis (DEA) and stochastic frontier analysis (SFA) methods by estimating technical efficiency in the manufacturing industry in the selected provinces of Turkey by using panel data for the same period. By comparing the efficiency scores obtained from these two methods, they find that there is a significant difference in ranking of provinces in respect of the two methods, and average firm size and regional agglomeration have an impact on efficiency.

For a different period (1992-2001) and using a different approach, Alvan (2008) investigates the sources of growth in the Turkish manufacturing industry. For this purpose, a two-deflator growth accounting approach is applied that is based on the theory of capital, not the theory of production as in the traditional approach and TFP is defined as real-cost reduction- another element of economic growth. The two-deflator approach, put forward by Harberger (1991), allows for a more detailed and complete evaluation of the contribution of human capital quality to growth. One of the main differences between the previous empirical studies and the two-deflator method is that the latter method is able to decompose human capital's contribution to growth and analyze it in detail by sectors. The paper concludes that a decomposition analysis of human capital contribution under total labor contribution to value-added growth shows mostly negative values under this approach between 1992 and 2001.

The availability of longitudinal data at the plant level has allowed researches to analyze productivity dynamics by taking into account the heterogeneity of plants. In Turkey, empirical studies use plant level data mostly in order to investigate productivity changes during increased trade openness and participation in international activities.

For example, Taymaz and Yılmaz (2007) analyze the productivity response to trade barrier reductions for Turkish manufacturing plants for 51 four-digit SIC industries spanning the period of 1984-2000, following the procedure of Olley and Pakes. They observe that productivity gains are largest in import competing industries, compared to export-oriented and non-traded sectors. Moreover, productivity actually increased in the manufacturing sectors and this is examined along with increased import penetration rates in the aftermath of the Customs Union in 1996.

Following the same procedure, Özler and Yılmaz (2009) examine the effects of trade policy changes on the evolution of productivity in the Turkish manufacturing industry for the 1983–1996 period. They find that productivity gains are largest in import-competing industries with highest gains reaching 8% per year during periods of rapid decline in protection rates. Moreover, they conclude that productivity improvements due to declining protection rates are important especially in import-competing sectors and also increase with the plant size.

In a recent study, Taymaz et al. (2009) evaluate the plant-level total factor productivity in the manufacturing industry from 1984 to 1996. They show that after 1988, TFP followed an upward trend until 1993, with an average growth rate of 5% per annum, before it got completely stalled after the 1994 economic crisis. In addition to their previous empirical work, they also investigate the direction of the causality between real wages and the productivity by implementing the Granger causality test in a panel data environment. For each 3-digit ISIC industry, they regress the plant level productivity term (labor or total factor productivity) on the lagged plant level real wage rate, lagged plant level productivity as well as the year and plant indicators. Their evidence supports the hypothesis that the causality runs from real wages to productivity.

2.2. Productivity and Information and Communication Technologies

Given the importance of productivity in the process of economic growth and the positive impact of information and communication technologies (ICTs) on productivity, much research effort has been devoted to address the impact of ICT on productivity growth. Early firm level ICT use surveys, piloted by OECD, were implemented in Canada, Scandinavia, Australia and the US in the late 1990s. Starting in 2001, the EU began a sustained program of implementation and development of ICT use surveys, in which member states were supported in developing practical survey instruments around a common core of questions (Franklin et al., 2008). By 2002, researchers started linking the surveys to business output and employment data to test whether productivity differences between firms could be linked to use of information technology or communications.

Using firm level data to study the relationship between ICT and firm performance, empirical studies adopted different methodologies. The first was included ICT capital stock at firm level as a separately identified capital input in total factor productivity (TFP) analysis (Brynjolfsson and Hitt, 2001; Hempell, 2002). Another methodology was to include ICT capital as an additional ICT measure, alongside other such ICT measures as Internet use or number of employees using ICT (Maliranta and Rouvinen, 2003). The third included ICT capital stock with measures of innovation and organizational change (Van Leeuwen and Van der Wiel, 2003). The last methodology was to include measures of computer network use as an additional determinant of TFP in a productivity regression equation (Atrostic and Nguyen, 2002).

A recent and extensive work by Van Reenen et al. (2010) evaluating the impact of ICT on productivity uses a panel of European firms drawn from the AMATECH database. This database includes approximately 19,000 firms across 13 countries covering the period 1998-2008. They use a measure of ICT capital that is constructed as the number of laptops and PCs per worker that is effectively a hardware-only measure of ICT capital. Using GMM-System method, they find that a 10% increase in ICT capital is associated with a 0.9% increase in output. More pointedly, it is higher than the share of ICT capital in output (which is approximately 1-2% for this sample) and therefore suggests very high returns to ICT capital.

To best of our knowledge, there is only one study that analyzes the productivity of the ICT sector, but only for consumer electronics in Turkey. Taymaz and Yılmaz (2007) examine the evolution of automobile and consumer electronics industries and the role of macroeconomic policies since the 1980s in order to shed light on the factors behind these sectors' export performance. They focus on the consumer electronics sector (or, more specifically, cathode ray tube color television receivers) in analyzing Turkey's integration with the world economy in ICT industries. They calculate total factor productivity over the period 1989-2001 using the Olley-Pakes method wherein TFP growth series are imputed for the 2001-2006 period using an index for labor productivity. They find that consumer electronics industries achieved above average growth rates in productivity since the mid-1990s, whereas the automobile industry's productivity growth performance is almost equal to the manufacturing average.

3. The Data Characteristics

The analysis in this research is based on the Annual Industry and Service Statistics Database obtained from Turkish Statistical Institute (TURKSTAT). This database covers all manufacturing firms employing 19+ workers and 60% of the firms employing less than 19 workers and provides firm level information on many firm-specific variables. We also used 4-digit industry price indices obtained from TURKSTAT to make the variable measured in monetary values real.

Developing a measure of the stock of capital, *K*, is a challenging exercise because the capital stock variable is not available in the data set but firm's investment and amortization cost. In order to construct separate stocks for ICT capital and conventional (non–ICT) capital from investment data, we compute investment on conventional capital as total investment expenditures minus ICT expenditures and use producer price index to deflate the investment series. Given the deflated investments for both types of capital, we apply the perpetual inventory method with constant depreciation rate to construct the capital stocks for ICT and non-ICT. The methodology used is to proxy the capital stock of the initial year by using amortization[3], adding the investment and subtracting depreciated capital.

Letting K, i, and d stand for capital, investment and depreciation rate respectively, the capital stock is measured as follows:

$$K_{t+1} = K_t + i_{t+1} - d*K_{t+1} \qquad \textbf{(1)}$$

Note that in the equation above, K_t is the capital stock of the year 2003 and is proxied by amortization.

In calculating ICT capital, which is the first attempt for Turkish manufacturing firms, we assume that the ratio of ICT investment is equal to ICT capital stock ratio. Therefore, in order to find the magnitude of ICT capital, we first found the ratio of ICT investment, namely ICT Investment Ratio. We took the three-year-moving average of ICT investment ratio. We, then, multiplied ICT investment ratio with the total capital stock to obtain the firm's ICT capital stock. To find the conventional capital, we simply subtract ICT capital from total capital stock.

4. The Impact of ICT on Output Growth and Productivity

This section examines the impact of ICT on output and labor productivity in Turkish manufacturing industry by using firm level data over the period 2003-2010. We consider both growth accounting and regression-based approaches in our analysis below.

4. 1. Impact of ICT on Output Growth: A Growth Accounting Approach

The most direct way to model the impact of ICT on growth is to distinguish capital into two sub-aggregates, ICT and non-ICT capital, and find the differential impact of ICT capital and non-ICT capital on output growth (O'Mahony and Vecchi, 2005). One would expect additional productivity gains from investing in ICT capital compared to non-ICT capital, conventional capital. Suppose the production function of the i^{th} firm takes the following Cobb-Douglas type production function with Hicks-neutral technology:

$$Q_{it} = A_{it} F(K_{it}, L_{it}) \qquad \textbf{(2)}$$

where Q is output/value added, A is technology, K is capital, and L is labor, and i and t denote firm and time respectively. Assuming that capital is composed of two types: ICT (I) and non-ICT capital (N) and constant returns to scale, output growth can be decomposed into four

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[3] In calculating the capital stock, in fact, we used three different depreciation rates: 7.5%, 10%, and 15%. However, results were quite comparable and we report only those based on the 10% depreciation rate.

components: contribution of TFP, labor input, non-ICT capital and ICT capital inputs (see for example, O'Mahony and Vecchi, 2005 and Jorgenson et al. 1987).

$$\Delta q_{it} = \Delta tfp_{it} + s_{li(t,t-1)}\Delta l_{it} + (1 - s_{li(t,t-1)})(s^{N}_{ki(t,t-1)}\Delta k^{N}_{it} + s^{I}_{ki(t,t-1)}\Delta k^{I}_{it}) \qquad \textbf{(3)}$$

where s_i is the share of labor in value added, and $(s_k^N + s_k^I = 1)$ are the shares of ICT and non-ICT capital in total. The shares are the mean value of the two years. In equation (3) the value of $\left[(1 - s_{li(t,t-1)})(s^{I}_{ki(t,t-1)}\Delta k^{I}_{it})\right]$ will give the contribution of ICT on output growth.

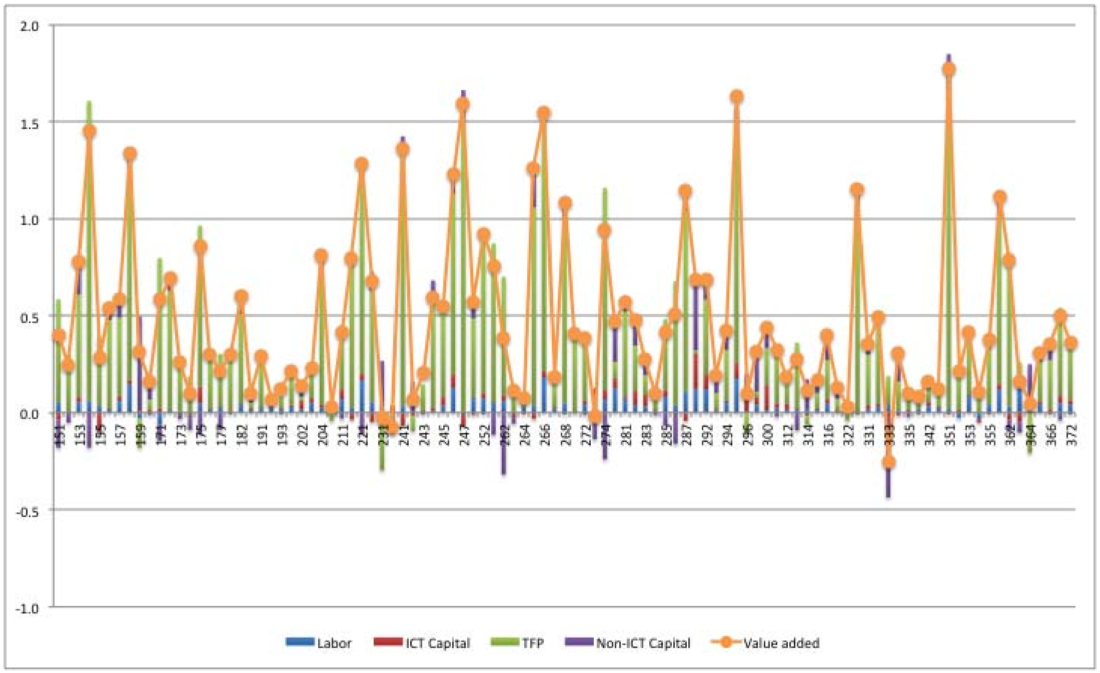
4. 2. Impact of ICT on Output Growth: Findings from Growth Accounting

The findings on the impact of ICT capital on output growth based on the equation (3) above are given in Graph 1. This graph demonstrates a decomposition of value added growth for each sector at the 3-digit level in Turkish manufacturing industry over the period 2004-2009 by distinguishing ICT and non-ICT capital. At a first glance, the contribution of non-ICT capital to value added growth appears to be smaller in most of the sectors than growth based on the capital aggregate. However, there are several sectors in which the contribution of non-ICT capital is higher than that estimates without disaggregating the capital stock. Processing and preserving of fruit and vegetables (153), manufacture of grain mill products, starches and starch products (156), printing and service activities related to printing (222), manufacture of pesticides and other agro-chemical products (242), manufacture of man-made fibres (247), manufacture of bricks, tiles and construction products, in baked clay (264), manufacture of other non-metallic (296) and manufacture of office machinery and computers (300). Moreover, manufacture of machinery for the production and use of mechanical power, except aircraft, vehicle and cycle engines (291) sector exhibited the highest gain in ICT capital growth (14%) per annum.

The contribution of ICT capital to value added growth is larger than the contribution of non-ICT capital in a the sectors of production, manufacture of builders' carpentry and joinery (203), manufacture of soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations (245), manufacture of articles of concrete, plaster and cement (266), manufacture of weapons and ammunition (296) and manufacture of instruments and appliances for measuring, checking, testing, navigating and other purposes, except industrial process control equipment (332).

The contribution of non-ICT capital to value added growth is greater more than the contribution of ICT capital in a majority of the sectors, especially in the manufacture of grain mill products, starches and starch products (156), manufacture of beverages (159), manufacture of knitted and crocheted fabrics (176), manufacture of other wearing apparel and accessories (182), tanning and dressing of leather (191), manufacture of basic iron and steel and of ferro-alloys (271), manufacture of agricultural and forestry machinery (293), manufacture of machine-tools (294), manufacture of lighting equipment and electric lamps (315), manufacture of radio, television and communication equipment and apparatus (321 & 322).

Graph 1. Factor input contributions (ICT and non-ICT capital) to productivity growth, NACE Rev.1 (3-digit), 2004-2009 average



Source: Authors calculations based on TURKSTAT (2013) data.
Notes: In some of the sectors, the average contribution of inputs to value added growth has been calculated with 2009 data missing such as 221, 275, 353, 355, 362, 365, 371, and 372. Moreover, for sector 363 three years data are missing including 2009, for sectors 231 and 335 two years data are missing including 2009, for sectors 333 and 351 three years data are missing as well.

The manufacture of man-made fibres (247), manufacture of articles of concrete, plaster and cement (266) are the fastest growing sectors in Turkey through decomposition of value added growth. When we evaluate the contribution of factor inputs to productivity by distinguishing between ICT and non-ICT capital, both of the above listed sectors together with manufacture of other special purpose machinery (295) and building and repairing of ships and boats (351) display a high average value added growth/year. The contribution of non-ICT capital to productivity is higher than the contribution of ICT capital in manufacture of man-made fibres (247) and manufacture of other special purpose machinery (295) sectors. In manufacture of articles of concrete, plaster and cement (266) sector, ICT capital accumulation is higher than the non-ICT capital accumulation. Finally, the contribution of non-ICT capital to value added growth is negative and higher than ICT capital in building and repairing of ships and boats (351) sector.

It is hard to say that ICT capital accumulation has a significant role in the improvement of value added growth in Turkish manufacturing industry. The growth rate of value added in Turkish manufacturing industry was mainly triggered by factors other than ICT capital accumulation. There are some sectors where the impact of ICT capital accumulation is higher than that of the other sectors in the average. These positive and significant contributions of ICT capital are attained in manufacture of other textiles (175), manufacture of other chemical products (246), manufacture of tanks, reservoirs and containers of metal; manufacture of central heating radiators and boilers (282), manufacture of machinery for the production and use of mechanical power, except aircraft, vehicle and cycle engines (291), manufacture of weapons and ammunition (296) and manufacture of office machinery and computers (300) sectors. The highest rate for ICT capital contribution to productivity growth is in manufacture of machinery for the production and use of mechanical power, except aircraft, vehicle and cycle engines (291) with 18% growth rate per annum.

4. 3. Modeling the Impact of ICT on Productivity: An Econometric Approach

There are several well-known problems with growth accounting or index number methods. In particular, they describe productivity patterns but do not provide a model in which to evaluated or interpret causal connections between changes in inputs, such as ICT, and productivity. With constant returns to scale, typical growth accounting methods measure the contribution of ICT capital to productivity growth by its expenditure share in production. Additionally, if there are externalities related to factors (such as knowledge spillovers from human capital), they will be included in the residual and the contribution of these factors will be underestimated (see for example, Sianesi and Van Reenen (2003) for a survey of the role of human capital in growth). Finally, the typical growth accounting paradigm is one of static long-run equilibrium and takes no account of adjustment costs (Van Reenen et al., 2010).

An alternative that can address this issue is an econometric model and we us such an alternative in our analysis below to explore the impact of ICT on labor productivity. In order to check for the impact of ICT on output growth, we begin with the Cobb-Douglas production function specification:

$$Q_{it} = A_{it} L_{it}^{\beta_L} K_{it}^{\beta_K} \quad \textbf{(4)}$$

where;

$$K_{it} = K_{it}^{I} + K_{it}^{N} \quad \textbf{(5)}$$

Labeling the disaggregated capital input as ICT (K^I) and non-ICT capital (K^N) equation (4) can be written as (O'Mahony and Vecchi, 2005 and Van Beveren (2012):

$$q_{it} = \beta_0 + \beta_l l_{it} + \beta_k^N k_{it}^N + \beta_k^I k_{it}^I + \varepsilon_{it} \quad \textbf{(6)}$$

Dividing the equation (6) by labor will yield labor productivity:

$$LP_{it} = \beta_0 + \beta_k^N (k-l)_{it}^N + \beta_k^I (k-l)_{it}^I + \varepsilon_{it} \quad \textbf{(7)}$$

One of the main generic issues related to the estimation of productivity specifications is the problem of unobserved heterogeneity, since there are many factors correlated with productivity that we do not measure. The idiosyncratic characteristics about the management of each firm—the skill of the managers, specific know-how, corporate culture, and the capacity to acquire intangible resources—could have a significant influence on productivity (Badescua and Garces-Ayerbe, 2009: 125). Unobserved firm-specific factors positively correlated with ICT capital, like firms with innovative ability are likely to invest more in ICT, will cause the coefficient, β_k^I, to be biased upward (Van Reenen et al., 2010). Fixed effects may address in part the unobserved heterogeneity (these can be viewed as instrumental variables) but the endogeneity of input decisions also suggests an IV procedure. The factor inputs (such as ICT) are chosen by firms and may not, therefore, be exogenous when included in the production function. The techniques for dealing with this latter issue utilize instruments that are usually based on lagged values of the dependent and explanatory variables (see for a detailed discussion, Blundell and Bond, 1998 and 2000; Olley and Pakes, 1996). We employ these methods using generalized methods of moments (GMM) methods to deal with the endogeneity arising from the input decisions of firms. Specifically, after first-differencing the production function to address the potential fixed effects, we use lagged levels of inputs as instruments for changes in the inputs (Wooldridge, 2009). However, because inputs tend to be highly persistent over time, lagged levels of inputs tend to be only weakly correlated with input changes (Blundell and Bond, 1998). In our experience with our empirical setting, the use of lagged inputs to instrument for changes in inputs often caused the capital coefficient to be biased downwards and often insignificant that led to unreasonably low estimates of returns to scale. In response to these types of unsatisfactory results due to weak instruments, Blundell and Bond (1998) propose an extended GMM estimator. They attribute the bad performance of standard IV estimators to the weak instruments used for identification. They propose an extended (system) GMM estimator using lagged first-differences of the variables as instruments in the level equations and find that this estimator yields more reasonable parameter estimates. They also stress the importance of allowing for an autoregressive component in the measurement of firm productivity (see for a detailed discussion, Van Beveren, 2012).

The formal specification of the GMM model to be estimated is thus modified to:

$$q_{it} = \beta_0 + \beta_q q_{i,t-1} + \beta_l l_{it} + \beta_k^N k_{it}^N + \beta_k^I k_{it}^I + \varepsilon_{it} \quad \textbf{(8)}$$

Note that Equation (8) may also be transformed to reflect the impact of ICT on labor productivity (*LP*) by dividing by the labor input:

$$LP_{it} = \beta_0 + \beta_q (q-l)_{i,t-1} + \beta_k^N (k-l)_{it}^N + \beta_k^I (k-l)_{it}^I + \varepsilon_{it} \quad \textbf{(9)}$$

The estimated value of β_k^I will give the impact of ICT on output growth in equation (8) and on labor productivity in equation (9). This coefficient indeed is the elasticity of productivity with respect to ICT-capital. We expect this coefficient to be statistically significant and higher than that of non-ICT capital coefficient, β_k^N.

4.4. The Impact of ICT on Productivity: Estimation Results

Estimation results of the impact of ICT on productivity are given in Table 1. The fixed effects (Models A and B) and GMM estimation (Models C, D, and E) results show that the estimated coefficient of ICT capital (*ICT_KL)* is significant and positively related with labor productivity. More importantly, while there is a significant and positive estimated relationship between labor productivity and ICT (*ICT_KL*) and non-ICT capital (*NON_ICT_KL)*, we found that the coefficient of ICT-capital is larger than that of non-ICT capital in all estimated models. This implies that ICT-capital is more productive than conventional capital.

GMM results in Table 1 also identify the global crises starting in 2008 in the World, which affected Turkish manufacturing industry as well. We find that labor productivity shows remarkable productivity decreases in the year 2009.

Table 1. The impact of ICT on productivity, 2003-2010, fixed effects and GMM estimation results, dependent variable is log of labor productivity

	Fixed Effects		GMM		
VARIABLES	***Model A***	***Model B***	***Model C***	***Model D***	***Model E***
Lag_LP			-0.0046	0.0049	0.0492***
			(0.0183)	(0.0182)	(0.0138)
ICT_KL	0.0230***	0.0194***	0.0196***	0.0195***	0.0151***
	(0.0034)	(0.0034)	(0.0049)	(0.0049)	(0.0050)
NON_ICT_KL	0.0196***	0.0160***	0.0142***	0.0145***	0.0098**
	(0.0033)	(0.0033)	(0.0048)	(0.0049)	(0.0050)
year-2004		-0.222***			0.0637
		(0.0370)			(0.0521)
year-2005		-0.430***			-0.165***
		(0.0357)			(0.0445)
year-2006		0.0433			0.280***
		(0.0356)			(0.0335)
year-2007		-0.0610*			0.114***
		(0.0360)			(0.0315)
year-2008		-0.0736**			0.0434
		(0.0365)			(0.0279)
year-2009		-0.0351		-0.0888***	
		(0.0377)		(0.0266)	
Constant	8.992***	9.177***	9.071***	8.995***	8.574***
	(0.0433)	(0.0509)	(0.182)	(0.180)	(0.144)
Observations	79,866	79,866	43,243	43,243	43,243
Number of firms	22,864	22,864	15,199	15,199	15,199

Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1
Source: Authors calculations based on TURKSTAT (2013) data.
Notes: Depreciation rate is assumed to be 10% in calculating capital stock.

5. Conclusion and Policy Implications

This study examines the dynamics and sources of value added and productivity growth in Turkish manufacturing industry using firm level data. The analysis is based on the firm level data obtained from TURKSTAT (2013) that provides significant evidences for Turkish manufacturing industry in 2000s. This study is the first attempt to quantifying the difference between ICT and conventional capital's contribution to Turkish output growth using growth accounting methodology, and to estimate the impact of ICT on labor productivity using both fixed and dynamic panel data model.

The findings of this research based on growth accounting results suggest that ICT capital accumulation has no special role vis-a-vis non-ICT capital in contributing to value added growth in the Turkish manufacturing industry during 2004-2009. The highest contribution of ICT capital to output growth is in the manufacture of machinery for the production and use of mechanical power, except aircraft, vehicle and cycle engines (291) sector. This sector is classified as an ICT-using sector. There are some sectors where ICT capital substituted for non-ICT capital. These sectors are preparation and spinning of textile fibres (171), manufacture of other textiles (175), manufacture of knitted and crocheted articles (177), manufacture of pulp, paper and paperboard (211), publishing (221), manufacture of basic precious and non-ferrous metals (274), manufacture of cutlery, tools and general hardware (286) and recycling (37). In printing and recycling sectors, the accumulation of non-ICT capital becomes negative and it is substituted by ICT capital, verifying their classification as ICT-using sectors. The positive and significant contribution of ICT capital accumulation to productivity sounds reasonable when we distinguish sectors into ICT-using and ICT-producing sectors. In their research, Van Reenen et al. (2010) and Stiroh (2002) classified manufacture of machinery for the production and use of mechanical power, except aircraft, vehicle and cycle engines (291) and manufacture of weapons and ammunition (296) sectors as ICT-using sectors. Whereas, manufacture of office machinery and computers (300) sector has been classified as ICT-producing sector. Moreover, the above stated sectors classified as medium and high technology intensive sectors in their aggregation of the manufacturing industry according to technological intensity that is based on NACE Rev. 1.1 at 3-digit level.

Our findings based on both static and dynamic panel data models, on the other hand, show that ICT capital is more productivity enhancing than conventional capital. The contribution of ICT capital to labor productivity in Turkish manufacturing industry is larger about 25% to 50% than that of conventional capital.

The results of growth accounting and econometric estimations do not lead to the same conclusion that investing more in ICT capital enhances productivity growth. The reason rests with the interpretation of the two approaches. ICT capital accumulation does not increase directly the growth of output but increases the productivity of labor. Therefore we found higher impact of ICT capital accumulation on labor productivity growth but on value added growth. These previous conclusions are mostly based on studies grounded in the growth-accounting tradition and are broadly confirmed by our study. However, while growth accounting may capture some of the direct effects of ICT (those related to ICT capital deepening and to TFP in ICT producing sector), it cannot account for the indirect effects of ICT that are driven by the consequences of investment and diffusion of ICT on the productivity of ICT using sectors (Biagi, 2013). In order to fully understand what determines the impact of ICT on productivity especially in ICT-using sectors, broader data at firm level is necessary. Moreover, using a regression-based approach, both at sector and firm level data, allows for a more in depth view of the relationship between ICT and productivity growth.

Findings of this research that ICT capital is more productive than conventional capital would suggest encouraging the firms to invest and use more ICT intensive capital in that they may bring about further productivity gains. The first question for policy makers is whether policy interventions are needed to realize the potential impact of ICT on the economy. The evidence from firm and plant level data points out the presence of spillover and externality effects generated by ICT capital. This implies that there may be a role for public polices to support investment in ICT, such as designing policies for supporting R&D in the ICT sector, as there are two types of externalities, one related to ICT capital and the other to R&D capital. Second, if there is a case for public policy intervention, this may take essentially three forms: direct public investment in ICT, subsidies that affect the private price of ICT investment in order to bring it more in line with the socially optimal price, and regulatory interventions to reallocate the costs and benefits between economic agents.

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Appendix A.1 NACE Rev1. Sector Groups and Descriptions, 3-digit

Sector	Description
151	Production, processing and preserving of meat and meat products
152	Processing and preserving of fish and fish products
153	Processing and preserving of fruit and vegetables
154	Manufacture of vegetable and animal oils and fats
155	Manufacture of dairy products
156	Manufacture of grain mill products, starches and starch products
157	Manufacture of prepared animal feeds
158	Manufacture of other food products
159	Manufacture of beverages
160	Manufacture of tobacco products
171	Preparation and spinning of textile fibres
172	Textile weaving
173	Finishing of textiles
174	Manufacture of made-up textile articles, except apparel
175	Manufacture of other textiles
176	Manufacture of knitted and crocheted fabrics
177	Manufacture of knitted and crocheted articles
181	Manufacture of leather clothes
182	Manufacture of other wearing apparel and accessories
183	Dressing and dyeing of fur; manufacture of articles of fur
191	Tanning and dressing of leather
192	Manufacture of luggage, handbags and the like, saddlery and harness
193	Manufacture of footwear
201	Sawmilling and planing of wood; impregnation of wood
202	Manufacture of veneer sheets; manufacture of plywood, laminboard, particle
203	Manufacture of builders' carpentry and joinery
204	Manufacture of wooden containers
205	Manufacture of other products of wood; manufacture of straw and plaiting
211	Manufacture of pulp, paper and paperboard
212	Manufacture of articles of paper and paperboard
221	Publishing
222	Printing and service activities related to printing
231	Manufacture of coke oven products
232	Manufacture of refined petroleum products
241	Manufacture of basic chemicals
242	Manufacture of pesticides and other agro-chemical products
243	Manufacture of paints, varnishes and similar coatings, printing ink and mastics
244	Manufacture of pharmaceuticals, medicinal chemicals and botanical products
245	Manufacture of soap and detergents, cleaning and polishing preparations,
246	Manufacture of other chemical products
247	Manufacture of man-made fibres
251	Manufacture of rubber products
252	Manufacture of plastic products
261	Manufacture of glass and glass products
262	Manufacture of non-refractory ceramic goods other than for construction
263	Manufacture of ceramic tiles and flags

Sector	Description
264	Manufacture of bricks, tiles and construction products, in baked clay

Appendix A.1 (cont.) NACE Rev1. Sector Groups and Descriptions, 3-digit.

Sector	Description
265	Manufacture of cement, lime and plaster
266	Manufacture of articles of concrete, plaster and cement
267	Cutting, shaping and finishing of stone
268	Manufacture of other non-metallic mineral products
271	Manufacture of basic iron and steel and of ferro-alloys
272	Manufacture of tubes
273	Other first processing of iron and steel and production of non-ECSC ferro-alloys
274	Manufacture of basic precious and non-ferrous metals
275	Casting of metals
281	Manufacture of structural metal products
282	Manufacture of tanks, reservoirs and containers of metal; manufacture of central
283	Manufacture of steam generators, except central heating hot water boilers
284	Forging, pressing, stamping and roll forming of metal; powder metallurgy
285	Treatment and coating of metals; general mechanical engineering
286	Manufacture of cutlery, tools and general hardware
287	Manufacture of other fabricated metal products
291	Manufacture of machinery for the production and use of mechanical power,
292	Manufacture of other general purpose machinery
293	Manufacture of agricultural and forestry machinery
294	Manufacture of machine-tools
295	Manufacture of other special purpose machinery
296	Manufacture of weapons and ammunition
297	Manufacture of domestic appliances n.e.c.
300	Manufacture of office machinery and computers
311	Manufacture of electric motors, generators and transformers
312	Manufacture of electricity distribution and control apparatus
313	Manufacture of insulated wire and cable
314	Manufacture of accumulators, primary cells and primary batteries
315	Manufacture of lighting equipment and electric lamps
316	Manufacture of electrical equipment n.e.c.
321	Manufacture of electronic valves and tubes and other electronic components
322	Manufacture of television and radio transmitters and apparatus for line
323	Manufacture of television and radio receivers, sound or video recording or
331	Manufacture of medical and surgical equipment and orthopedic appliances
332	Manufacture of instruments and appliances for measuring, checking, testing,
333	Manufacture of industrial process control equipment
334	Manufacture of optical instruments and photographic equipment
335	Manufacture of watches and clocks
341	Manufacture of motor vehicles
342	Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers
343	Manufacture of parts and accessories for motor vehicles and their engines
351	Building and repairing of ships and boats
352	Manufacture of railway and tramway locomotives and rolling stock
353	Manufacture of aircraft and spacecraft
354	Manufacture of motorcycles and bicycles

355	Manufacture of other transport equipment n.e.c.
361	Manufacture of furniture

Appendix A.1 (cont.) NACE Rev1. Sector Groups and Descriptions, 3-digit.

Sector	Description
362	Manufacture of jewellery and related articles
363	Manufacture of musical instruments
364	Manufacture of sports goods
365	Manufacture of games and toys
366	Miscellaneous manufacturing n.e.c.
371	Recycling of metal waste and scrap
372	Recycling of non-metal waste and scrap

Source: Industry classifications, NACE Rev1, TURKSTAT (2013)