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Abstract

Although empirical evidence available suggests that information and communication technologies (ICT) have positively contributed to important sectors of the Mexican economy, it is still unknown to which extent ICT have truly contributed to productivity among these sectors. The increasing implementation and imports of ICT technologies, the growing demand for ICT-skilled human capital and training, the rising level of wages and the large demand and adoption of these technologies seem to indicate a positive correlation between ICT implementation and economic growth in Mexico. To answer whether ICT may be a key strategy for economic growth in the Mexican economy is the main purpose of this work.

JEL-classification: D24, D83, F43, J24, J31, O33.

Keywords: Information technology, total factor productivity, growth, knowledge, human capital, technology diffusion.

Zusammenfassung

„Ist Informations- und Kommunikationstechnologie (IKT) die Richtige Strategie für Ökonomischen Wachstum in Mexiko?“

Obwohl empirische Evidenz zeigt, dass Informations- und Kommunikationstechnologien (IKT) zu verschiedenen Sektoren der mexikanischen Wirtschaft positiv beigetragen haben, ist es noch unklar inwieweit sich die Produktivität in diesen Sektoren durch IKT erhöht hat. Durch die zunehmende Implementierung und die Importe von IKT, den wachsenden Bedarf nach qualifizierten IKT-Humankapital und Ausbildungsmöglichkeiten, die Verbesserung der Löhne in der Branche und die große Nachfrage und Einführung dieser Technologien zeigt sich eine positive Korrelation zwischen IKT-Implementierung und Wachstum der mexikanische Wirtschaft. Hauptzweck dieser Arbeit ist zu beantworten ob IKT eine der Hauptstrategien für ökonomisches Wachstum in Mexiko sein kann.

JEL-Klassifikation: D24, D83, F43, J24, J31, O33.

Schlagworte: Informationstechnologie, Produktivität, Wachstum, Humankapital, Technologietransfer.

1. Introduction

"We see the computer age everywhere except in the productivity statistics"
Robert Solow
Nobel Prize Winner

The impact of information and communication technology (ICT) in today's economy is undeniable. ICT is virtually everywhere, it has greatly changed our society and this change is indeed worth calling it the "third industrial revolution" (Kagami et al., 2004.) In fact, it would be hard to imagine how every day's life would be like if these technologies were not available. Faster computers, machines and telecommunications equipments have created important changes in the structure of goods, labor and financial markets (Cechetti, 2002), and have dramatically changed the traditional perspective of the world's economy. The ample implementation of ICT worldwide gave birth to a new e-conomy or, as many experts prefer to call it, a digital economy.

At the same time, the accelerated introduction of ICT into the economy has created numerous challenges for policy makers (Cechetti, 2002) as more and more countries around the world rapidly adopt ICT as a central part of their economic strategies and growth policies. The OECD concluded in its 2001 ministerial report (2003b) "The New Economy: Beyond the Hype", that ICT is important and has the potential to contribute to more rapid growth and productivity gains in the years to come. However, when compared to industrialized countries, most emerging economies do not appear to be taking advantage of the benefits of ICT. Several experts already talk about an existing and growing "digital divide" amid a selected group of countries that decidedly promote investment in ICT and several other countries who do not consider ICT investment as a strategic sector for economic development or do not have the necessary funds to implement it or develop it. In the particular case of Latin America, the Economic Commission for

Latin America and the Caribbean (ECLAC) warns that countries in the region must face the costs of making the transition to an information and knowledge-based society because the costs of not doing so are even greater (ECLAC, 2000.) On the other hand, countries who favor ICT-based industries and ICT-relevant research and education like Ireland, Korea and Finland have escalated to the top in the ladder of economic growth and benefits for their citizens. Another enticing incentive is the capacity of ICT to raise income and improve the economic growth rate as it offers opportunities to improve the environment, educational outcomes, health service delivery, and other government services (Grace, 2003.) Further advantage of ICT for countries being in the "digital divide" are the relative low opportunity costs for switching from old to new technology. These proportional low costs may indeed enable emerging countries to learn from experiences of advanced economies from the outset and implement these technologies more efficiently. A process called leapfrogging (Zehn and Pitt, 2003.) Miller (2001) affirms that ICT might enable developing countries to leapfrog faster over the development path taken by industrial countries, increase their rates of growth and "catch up" earlier than through other models of growth.

2. Antecedents

ICT alone is not to be considered as the magic remedy for boosting economic growth. Especially when considered that a successful implementation of ICT highly depends on the existing telecommunications infrastructure and the capacity of technology adoption in the host country. Technology adoption, in fact, is strongly correlated with the level of education or skilled workforce available. Under these considerations, most of the ICT industries are unlikely to offer poorer countries long-term sustainable economic growth as poorer countries and regions have stronger comparative advantage in low-skilled rather than high-skilled labor (Bellini et al., 2003.)

As Low (2000) affirms, in the information age the resource that matters is intellectual rather than physical. Another key aspect to consider is the lack of an adequate ICT policy. Additionally, the recent weakness of most OECD economics, associated with the failure of many dotcoms and the generalized collapse of ICT stocks have reinforced the skeptical view that the ICT revolution was short lived and largely driven by unsustainable, or one-time factors. For example, the drop in PC prices, the introduction of internet, building up of fiber-optic telecoms, etc. (Cohen et al., 2004.)

Nevertheless, despite skeptical views and averse conditions, increasing ICT use and production have the potential to influence economic growth positively (Zehn and Pitt, 2003.) There is now clear supportive evidence of an acceleration of productivity in service industries that are major purchasers of ICT such as finance, wholesale and retail trade (OECD 2004.) These gains not only reflect increased investment in ICT but also complementary innovations in business organization and policy (Neil and Lawrence, 2001.) The OECD (2003a) supports this evidence when it affirms that the services sectors, i.e. wholesale trade and financial services, are typically the most intensive users of ICT. These statements are not hard to believe if one observes the exceptional economic success of some major ICT producers, like East Asia and Ireland, which has generated interest in ICT production as a potential vehicle for greater prosperity and economic development (Zehn and Pitt, 2003.) Another example of how investment in ICT and knowledge development pays off is Finland. The country has surpassed the USA in terms of ICT size and growth, internet access and high-skilled ICT workers, with the resulting betterment of welfare in Finland (Goel et al., 2004.) Whether one may agree or disagree with the key importance of the ICT sector for the achievement of economic growth, and based on the empirical evidence, fact is that the world is experiencing a major transition into a knowledge-based economy where information and knowledge are the prime sources of value added. The paradigm that shifts toward a knowledge-based economy has focused the spotlight on the significance of ICT more than ever and governments across the world are formulating policy frameworks for this strategically important sector (KIEP, 2002.) The knowledge economy and ICT are set to affect employment and labor market (Low, 2000), which ultimately will reflect on economic growth.

However, assessing the contribution of ICT to growth can turn out to be a tricky exercise as the results are conditioned by the quality of the series (Melka et al., 2004.) Also, since the latest technologies have not been around for very long. Thus, convincing empirical time-series evidence on their impact is difficult to obtain (Quah, 1999.) Instead this paper, the first of a two-part series, focuses on showing significant empirical evidence on how ICT has positively impacted strategic variables of the Mexican economy like growing demand of ICT, higher productivity, increasing demand of high-skilled workforce, and a significant degree of technology adoption and raise in wages within the ICT sector.

3. ICT as determinant of economic growth?

Despite existing empirical evidence regarding the positive impact of ICT on economic growth, the productivity paradox and how the productivity gains of ICT users can be measured are still a matter of debate. The length of time required for ICT diffusion and the inherent problems involved in measuring productivity in services are the reason why it is so difficult to measure the contribution made by ICT to the economy (ECLAC, 2000.) On the other hand, it cannot be precisely defined which are exactly the variables or sectors of the economy that are positively influenced by ICT. Cohen (et al., 2004), mentions three channels through which ICT can affect growth: the traditional process of capital deepening, ICT as an instrument for innovative activity, and ICT as a contributor to the production sector to aggregate growth. Bellini (et al., 2003), notices that the increasing penetration of ICT in the economy is leading to increasing convergence of industrial structure and remarks about how industries characterizing the so-called "digital clusters" share at least three additional features: they employ a skilled workforce, they are knowledge-intensive and they are fast growing. Cechetti (2002) affirms that an increase in growth can be interpreted as the increased productivity arising from the efficient use of technology in production. In terms of wages, Tan and Lopez-Acevedo (2003) found out that firms adopting new ICT and knowledge -i.e. through FDI, joint ventures, own R&D, technology licensing and patents, exporting and imports of new technology equipment-, have a positive effect on the raising of productivity and wages.

Nonetheless, seizing the benefits derived from the implementation of ICT could be very difficult to achieve if a policy and institutional framework, an innovation system, education and lifelong learning, and information technology infrastructure and electronic development (Goel et al., 2004) are missing. Moreover, government's policy that strongly curtails private use of new technologies -excess taxation, insufficient access provision- can have adverse long-run consequences on growth in the economy (Quah, 1999.) Therefore, enhancing these capacities are a prerequisite to increase the welfare of society (Krüger, 1993.) Interestingly enough, with the quick positioning and expansion of wireless technologies,[1] physical ICT infrastructure seem not to be such an overwhelming problem when compared with the challenge of raising the level of education and skills of the available workforce within a short-term. As Low (2000) concludes, skill acquisition and upgrading forms are the only source of long-run sustainable growth and competitive advantage. This fact seems to be consistent with Paul Romer's model of endogenous

[1] Wireless services could be in fact extremely important to help countries with weak ICT infrastructure to quickly overcome the digital divide. A process often called leapfrogging. Kagami (et al., 2004), affirms that wireless, satellite and associated telecommunications technologies indeed help latecomers and will enable developing countries to catch up with developed nations faster than they thought they ever could.

technological change (1990.) Romer states how governments should emphasize investment in technical knowledge as the determinant of long-run economic growth and a reasonable form to increase returns to scale and steady-state endogenous growth in output per capita and in the stock of knowledge. It can be affirmed; therefore, that a positive impact of ICT on economic growth is strongly correlated, and should be established, on a knowledge-based society. For example, the primary factors propelling the high-growth of ICT in Taiwan are the high percentage of R&D workers, cultivation of professionals needed for national competition, and recruitment of foreign-educated professional talents (Chang and Yu, 2001.)

The relevant question is of course, how to overcome education and skill deficits and make the transition to an ICT-friendly knowledge-based society. Common sense would indicate the implementation of a strategy of higher investment in education, and research and development (R&D) as more educated and/or trained individuals earn higher incomes (Tan and Lopez-Acevedo, 2003.) However, this option demands an important amount of capital investment and a very long period[2] to achieve and see the results of such a strategy. Romer (1990) suggests that free international trade can act to speed up growth in an economy with a larger total stock of human capital. Schiff and Wang (2003) also confirm this hypothesis when they affirm that countries benefit more from foreign R&D spillovers the more open they are, as trade is an important mechanism through which knowledge and technological progress is transmitted across countries.

On the other hand, Markusen and Rutherford (2004), propose a very interesting alternative to overcome educational and skills deficits. They affirm that importing foreign experts allows the economy to produce skilled workers earlier and at a lower cost than through learning

[2] Most probably, it will take several years to wait and see the first results of such a strategy with the probable delay of economic growth for an entire generation.

from scratch: reinventing the wheel. The cases of India and Taiwan seem as well to reaffirm these theories. In Taiwan for example, the strategy of recruiting overseas personnel turned out to be very advantageous as scholars and experts from abroad returned to Taiwan and established several companies with the technology and concepts they brought (Chang and Yu, 2001.) In the Indian case, a large group of technically-qualified persons in the country is utilizing their Indian contacts in the USA and had formed the backbone of a rapid and continuing growth in ICT investment (Miller, 2001.) However, Quah (1999) insists that patterns of ICT demand emerge not just from developing skills and education in the population at large as they are affected also by government efforts at regulation. Whatever strategy is chosen, one thing remains clear, in an era of man-made brainpower industries, capitalism will need some very long-run communal investment in R&D, education and infrastructure (Low, 2000.) The main question at this stage, though, is whether ICT is positively influencing economic growth in Mexico.

4. Effect of ICT in the Mexican economy

> "*A knowledge economy and a knowledge society is where all economic and social activities revolve around information. An era of skill acquisition and upgrading forms the only source of long-run sustainable growth and competitive advantage*"
>
> Linda Low
> National University of Singapore

During the last years, and as a direct consequence of NAFTA, significant inflows of foreign direct investment and diffusion of new ICT have flown into the Mexican industry (Tan and Lopez-Acevedo, 2003.) Mexico's trade with its NAFTA partners had as well a large and significant impact on Mexico's total factor productivity of about 5.5 to 7.5% that has led to some convergence with the economies of Canada and the United States (Schiff and Wang, 2003.) Lopez-Acevedo (2002b) confirms that the growing adoption and demand of technology has raised the relative demand for more skilled workers and, consequently, reduced the demand for manual labor. This pace of ICT adoption and diminishing demand for manual labor has also being intensified because Mexico is no longer a poor country and it is not surprising that low-wage jobs should move elsewhere[3] (EIU, 2003.) Lopez-Acevedo (2002a) found out that there is an increasing amount of skilled workers with the likelihood of adopting more complex technology and that the effect of technological change and adoption of new ICT, both of which are believed to be relatively skill-intensive or skill-biased, are the possible explanation for the growing demand for training (Tan and Lopez-Acevedo, 2003.)

NAFTA may also have created competitive pressures for exporting firms to improve their technology through R&D, and indirectly through R&D to upgrade worker skills. In the study of Tan and Lopez-Acevedo (2003), they discovered that the impact of exporting on training is small but the impact on R&D is large and statistically significant. Schiff and Wang (2003) concluded that the impact of foreign R&D on the total factor productivity of Mexico's manufacturing sector is large for imports from Mexico's NAFTA neighbors but not for imports from the rest of the OECD. This evidence clearly indicates that the Mexican manufacturing sector not only manufacture labor-intensive simple products but also more complex ones using new technology (Guzman and Wilson.)

Regarding ICT investment, along 2000 Mexico imported ICT equipment that reached a value of US$ 3 billion. This amount of ICT investment represents half of the total USA exports of ICT to Latin America (Kagami, 2004.)

[3] In the twelve months after June 2001, no less than 545 manufacturing plants had left Mexico for low-wage countries like China, where wages per capita are about one tenth of their Mexican counterparts. This is about two manufacturing plants leaving each working day (Palma, 2003.)

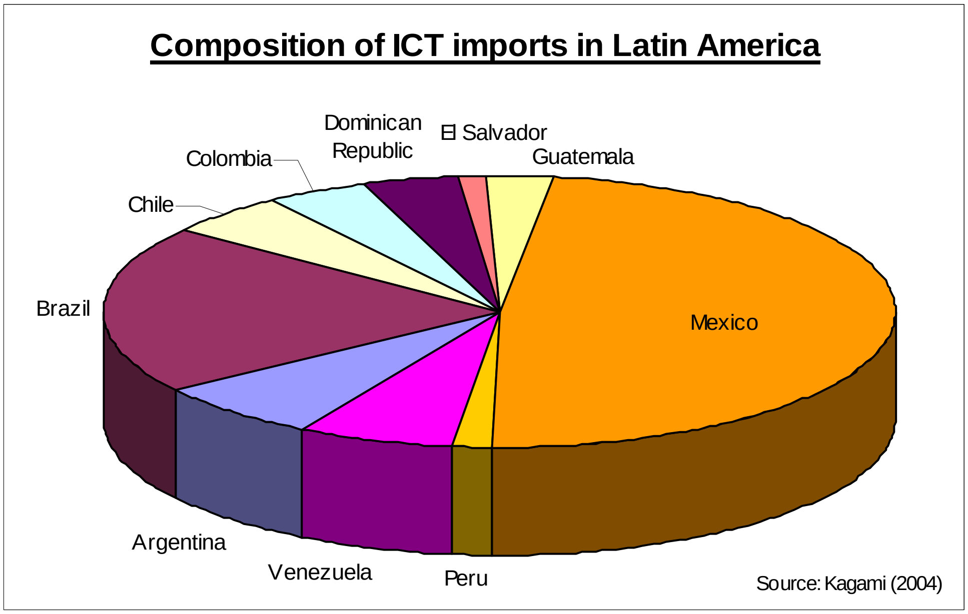

Figure 1. Composition of ICT imports in Latin America

Tan and Lopez-Acevedo (2003) state that firms adopting new ICT and knowledge, -i.e. through FDI, joint-ventures, own R&D, technology licensing and patents, exporting and imports of new technology equipment-, have a positive effect on total factor productivity and wages. The central state of Jalisco has been experiencing a boom in indigenously owned and operated subcontractors that build components for major technology firms such as Cisco Systems and IBM (Grace, 2003.) More specifically,[4] the Guadalajara region has shown notable increases in terms of investment, human resources, time dedication, qualifications and productivity (Rivera Vargas, 1999.) Consequently, the large majority of these firms are located in the Northern and Central Mexican States and they are more likely to adopt technology than firms located in other regions in Mexico (Lopez-Acevedo, 2002a) as observed in the following figure.

[4] For a more detailed information about the impact of ICT in Jalisco and Guadalajara see Rivera Vargas' publication: "Technology Transfer via University-Industry Relationship: The Case of the Foreign High Technology Electronics Industry in Mexico's Silicon Valley."

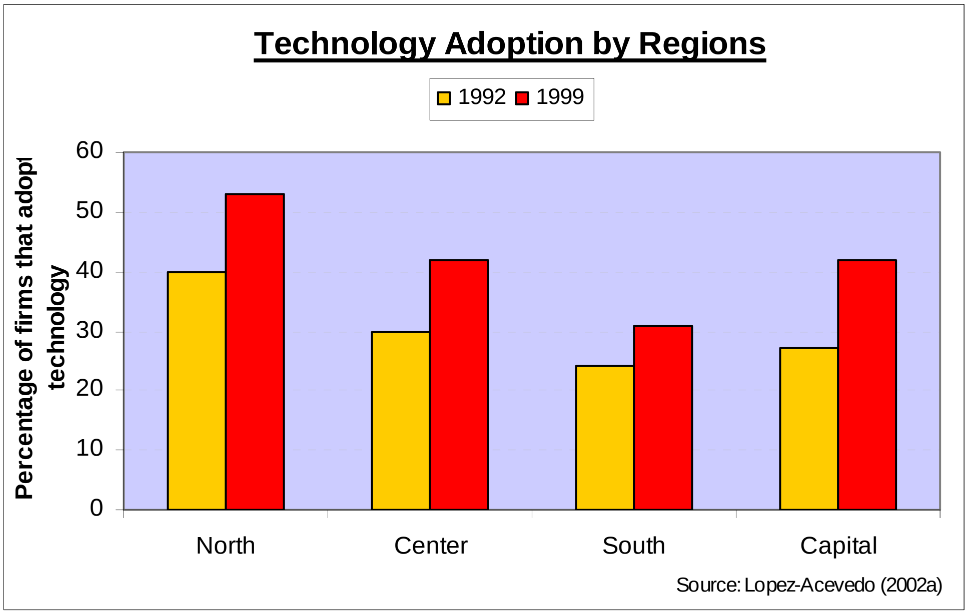

Figure 2. Technology adoption by regions

The OECD (2003b) also reports that Mexico is one of the OECD countries where productivity growth in ICT-using services improved during the 90s as observed in the next figure.

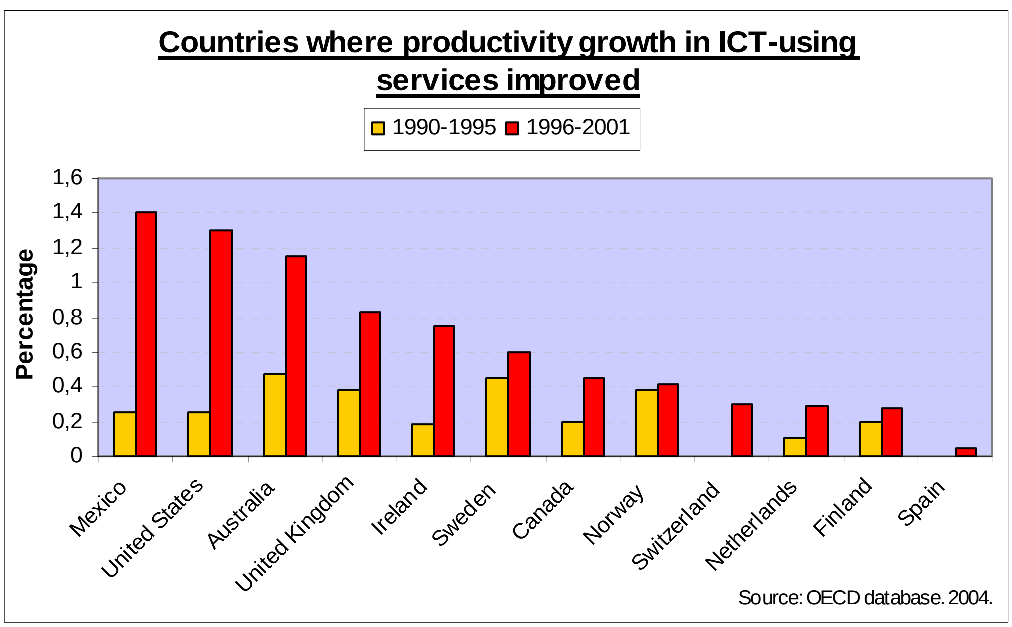

Figure 3. Countries where productivity growth in ICT-using services improved

As well, the contribution of ICT-using services to aggregate productivity growth substantially increased in Mexico and other countries like Australia, Canada, Ireland, the United Kingdom and the USA (OECD, 2003c.) One of the most interesting evidences is the share of ICT value added in the business sector. This share is about 6% and it shows that the country does not lie too far behind industrialized nations as observed in the next figure.

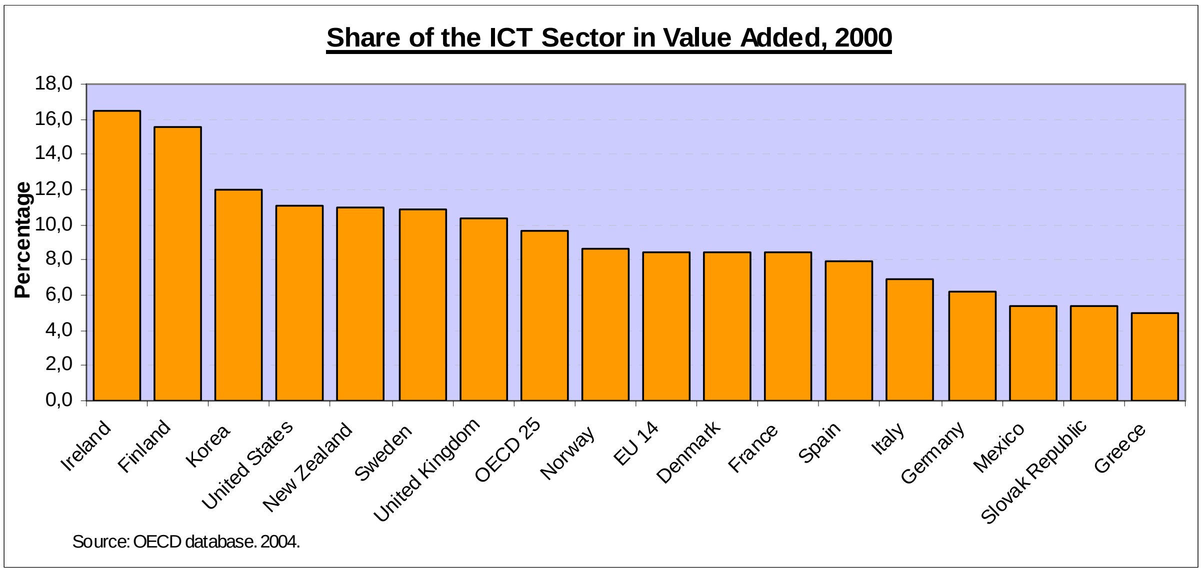

Figure 4. Share of the ICT sector in value added, 2000

Additionally, the OECD (2003a) reports in its study “ICT and Economic Growth: Evidence from OECD Countries, Industries and Firms,” that the GDP-per-hour-worked substantially increased in Mexico; although it is clear that this increase has not reached the levels recorded by leading countries in productivity like Ireland and Finland. Greece and Portugal are unambiguous examples of how their GDP-per-hour-worked has remarkably improved within a decade. It could be interesting to further analyze the Greek and Portuguese cases in the future and compare it to the Mexican case.

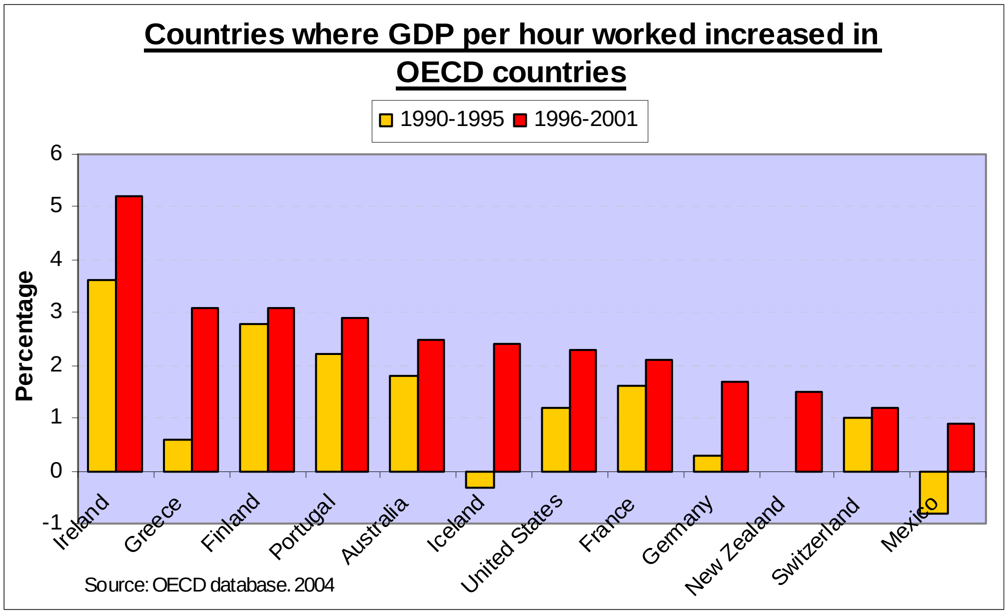

Figure 5. Countries where GDP per hour worked increased in OECD countries

A particularly interesting sector that is taking full advantage of ICT is the non-manufacturing industry as it presents high productivity growth based on substantial investment effort and the use of production techniques used in developed countries (Palma, 2003.) This sector is known for its exports of high-technology products that require high capital intensity and relatively high wages and salaries (Palma, 2003.) Despite the fact that the non-manufacturing sector in Mexico is a capital-scarce and relatively low-technology, Palma (2003) affirms that the non-manufacturing sector has begun to develop capital-intensive, relative high-wage, “technology-challenging,” and high-productivity-growth-potential products. This situation raises considerable possibilities to rationally and efficiently improve Mexico’s chances of “catching up” with developed countries and develop its comparative advantage and clearly contradicts the Hecksher-Ohlin-Samuelson theory.[5] Exports products from the non-manufacturing sector have

[5] Some trade theorists postulate that the only rational and efficient way for a developed country to increase its comparative advantages is to do so à la Hecksher-Ohlin-Samuelson. In the case of Mexico, the country should take advantage from its NAFTA-market-access privileges, meaning this that foreign direct investment chooses Mexico as a production platform and exploit one of the country’s main resource

high productivity growth potentials and could help to move up the technology “ladder” in the country.

It is also obvious that certain sectors worth to be evaluated and added to the final model are the areas of transports, communications, banking and financial services, as the benefits from ICT are likely to be important (Schiff and Wang, 2003.)

5. Models of economic growth

> “*The eternal verities of capitalism are growth, full employment, financial stability and rising real wages, which fluctuate and cause much volatility. In an era of man-made brainpower industries, capitalism will need some very long-run communal investment in R&D, education and infrastructure*”
>
> Linda Low
> National University of Singapore

Measuring the contribution of ICT to economic growth is probably one of the most discussed and unclear aspects in economics. Traditionally, the economic growth due to ICT is calculated with the growth accounting model developed by Jorgenson and Stiroh (1999,) which decomposes growth in both output and input categories. Outputs including computer and software consumption, computer and software investment, telecommunications investments and other outputs, whereas inputs include the capital services of computers, software, telecommunications equipments, labor input and other capital assets. To quantify the sources of ICT-related growth more explicitly, the extended production possibility frontier is shown in the next equation where time subscripts were eliminated to simplify the model:

$$Y\,(Y_{it}, C_c, I_c, I_s, I_m, D_c) = A\cdot X\,(K_{it}, K_c, K_s, K_m, D_{it}, D_c, L)$$

endowments, cheap labor force. Evidently, a strategy that is very static and unfavorable for Mexico’s long-term growth strategy.

Where the output variables are:

C_c: Computer and software consumption

I_c: Computer investment

I_s: Software investment

I_m: Telecommunications investments

D_c: Services of consumers' computers and software

Y_n: other outputs

and the input variables are:

K_c: Capital services of computers

K_s: Software

K_m: Telecommunications equipments

K_n: Other capital assets

D_c: Services of consumers' computers and software

D_n: Other durables

L: Labor input

A: represents the ability to produce more output from the same inputs.

These terms determine the corresponding extended growth accounting equation:

$$w_{Yn}\,\Delta\ln Y_n + w_{Cc}\,\Delta\ln C_c + w_{Ic}\,\Delta\ln I_c + w_{Is}\,\Delta\ln I_s + w_{Im}\,\Delta\ln I_m + w_{Dc}\,\Delta\ln D_c$$

$$=$$

$$v_{Kn}\,\Delta\ln K_n + v_{Kc}\,\Delta\ln K_c + v_{Ks}\,\Delta\ln K_s + v_{Km}\,\Delta\ln K_m + v_{Dn}\,\Delta\ln D_n + v_{Dc}\,\Delta\ln D_c + v_L\,\Delta\ln L + \Delta\ln A$$

Where w and v denote average shares in nominal income for the subscripted variable:

$w_{Yn} + w_{Cc} + w_{Ic} + w_{Is} + w_{Im} + w_{Dc} = v_{Kn} + v_{Kc} + v_{Ks} + v_{Km} + v_{Dn} + v_{Dc} + v_{L} = 1$

referred to a share-weighted growth rate as the contribution of an input or output.

The model takes into account the increasing cost differentials in the cost of software versus hardware, which implicitly assumes that these differentials in both input and outputs of software and hardware are perfect substitutes so that relative prices do not change. Finally, the results are expressed in terms of productivity growth.

Nevertheless, this model requires sound and reliable data time-series to obtain representative results. As Quah (1999) mentions, since ICT are relatively recent, it is difficult to obtain reliable empirical evidence. Another particularity of this model is that it only includes the static effects of investment and consumption of ICT-related goods and it does not include at all the dynamics of technology adoption, high-skills demand, R&D activities and the immediate impacts of education and/or training; therefore, underestimating the dynamism of price differentials, skills upgrading and technology adoption. However, the model of growth accounting can be very informative despite its shortcomings.

On the other hand, Romer’s model of endogenous economic growth serves as basis for a more appropriate model. The model of endogenous growth emphasizes on investment in technical knowledge as the determinant of long-run economic growth exhibiting increasing returns to scale and steady-state endogenous growth in output per capita and in the stock of knowledge. The model also includes the dynamic processes of R&D activities, the demand of high-skills/training and, most important, the impact of new technologies. To be more precise, it is simply not sufficient to split output into consumption and physical capital as in Jorgenson and Stiroh (1999) but building up the model of endogenous economic growth by assuming a simple

Cobb-Douglas function that includes exactly the specific variables affected by ICT implementation.

The division should be in terms of consumption, investment in physical capital and investment in human capital in the form of training and education. Expressed in terms of aggregate production function, this means extending the traditional two-factor function,

$Y_t = F(K_t, L; \text{Technology})$, to

$Y_t = F(K_t, L, H_{t;} \text{Technology})$

in order to emphasize the fact that the output level also depends on the stock of human capital H. According to Valdes (1999), the implication is that in the traditional Cobb-Douglas specifications of the aggregate production function:

$(1-\alpha)$, the share of labor in national income,

is overestimated because it includes both the labor share as such and the share of human capital. Whereas the share of "capital," α, is underestimated as it only includes the share of physical capital K, human capital H, and the effective labor $\Theta_t L_{t.}$

6. Conclusion

The main purpose of this paper is to identify and target those variables affected by the adoption and implementation of ICT in order to develop the corresponding model of economic growth for Mexico based on ICT adoption. From the empirical evidence shown, ICT may have indeed positively influenced key sectors of the Mexican economy. Hence, the assumption that ICT has contributed to economic growth appears to be affirmative. The most important findings supporting this statement are the apparent growth in the total factor productivity, the growing demand of training and ICT-skilled human capital, the increasing level of ICT-related wages, and the rising implementation and importing of ICT technologies. Although in the Northern and Central regions of Mexico, where the level of ICT adoption was larger and a larger GDP expansion is taking place, it could be interesting to further research what is the real level of economic growth due to the influence of the empirical evidence just mentioned. A result of a growth accounting a la Jorgenson and Stiroh could definitively provide a more complete picture on how truly ICT has contributed to economic growth in the country.

Nevertheless, it should not be let aside the positive side effects of ICT use and implementation that are not measured in the model of Jorgenson and Stiroh. For example, growth that is not based solely on exports, like the non-manufacturing sector -which is creating more industries and welfare (Palma, 2003)-, growth due to skill upgrading and training, and growth caused by the creation of new ICT enterprises.

Taking into account the obvious linkage amid the creation/investment of technical knowledge, in the form of ICT-skilled human capital, and the determinants of faster and long run economic growth; Romer’s model of endogenous growth seems to confirm the principles that long-term economic growth can only be achieved through technological change and investment in a knowledge-based society. In conclusion, the empirical evidence available suggests a positive correlation between ICT implementation and economic growth in Mexico and; therefore the further development and implementation of ICT in the country should be extended as a mechanism to achieve economic growth in the long-term.

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