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Artículos científicos

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ICT and Higher Education in Mexico: A State-Level Productivity Analysis

TIC e educação superior no México: uma análise da produtividade em nível estadual

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Resumen

El objetivo de esta investigación fue analizar empíricamente los cambios en la productividad total de los factores (CPTF) del uso de las tecnologías de la información y la comunicación (TIC) en los principales indicadores de la educación superior durante 2010-2018 en México. Con un panel de 32 estados con información anual, se estimó el índice de Hicks-Moorsteen (HMTFP) para cada uno, bajo el supuesto de rendimientos variables a escala. Los resultados mostraron una caída promedio en los CPTF que oscila entre -5.09 % y 3.29 %, al considerar el desempeño conjunto de todas las entidades federativas. Se concluye que existe una imperativa necesidad de fortalecer la infraestructura de las TIC y su uso en el sector educativo, especialmente en el nivel superior.

Palabras clave: educación superior, productividad, TIC.

Abstract

The purpose of this research was to empirically analyze the total factor productivity changes (TFPC) of information and communication technologies (ICT) use in higher education principal indicators during 2010-2018 in Mexico. Using a panel of 32 states with annual information, the Hicks-Moorsteen index (HMTFP) was estimated under the assumption of variable returns to scale. The results showed an average drop in TFPC ranging from -5.0 9% to 3.29 % when considering the performance of all states. In conclusion, there is an imperative need to strengthen ICT infrastructure and its use in the education sector, especially at the higher education level.

Keywords: higher education, productivity, ICT.

Resumo

O objetivo desta pesquisa foi analisar empiricamente as mudanças na produtividade total dos fatores (TCFP) do uso de tecnologias de informação e comunicação (TIC) nos principais indicadores do ensino superior durante 2010-2018 no México. Com um painel de 32 estados com informações anuais, o índice de Hicks-Moorsteen (HMTFP) foi estimado para cada um deles, sob a hipótese de retornos variáveis à escala. Os resultados mostraram uma queda média da CPTF que oscila entre -5,09% e 3,29%, quando considerada a atuação conjunta de todos os entes federativos. Conclui-se que há uma necessidade imperiosa de fortalecer a infraestrutura de TIC e seu uso no setor educacional, especialmente no nível superior.

Palavras-chave: ensino superior, produtividade, TIC.

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Introduction

One of the fundamental requirements for the use of information and communication technologies (ICT) is the technological infrastructure. At the international level, the International Telecommunication Union [ITU] (2017) has established an index to measure progress in the digitization of countries based mainly on indicators related to the availability or use of the Internet. , computer, fixed telephony (in homes) or mobile telephony. In this context, Mexico presents a significant lag among the countries of the Organization for Economic Cooperation and Development [OECD] (2019a); For example, for the year 2019 it was located in the penultimate place in households with Internet access, with 56.4% (list headed by South Korea and the Netherlands, with 99.7% and 98.4%), and in the percentage indicator of households With access to a computer, the situation was not very different, Mexico in last place, with 45.4%, well below the two Nordic countries that top the list, the Netherlands and Iceland, with 97.6% and 97.3%, respectively.

Compared to the leading countries in ICT indicators, Mexico presents particularities that make up an additional challenge: the amount of population, geography, network infrastructure, in addition to not being a benchmark as a country that generates cutting-edge technology (although it is strategically located at the technological frontier). However, Mexico made significant efforts in connectivity, since from 2013 (the year in which the telecommunications reform was approved) to 2018 the number of households with internet connectivity increased by 6.1 million households, going from 12.2 to 18.3 million. , equivalent to or greater than the number of households in some of the listed European nations (such as Iceland, Norway, Switzerland or Sweden).

Likewise, Mexico presents a heterogeneity in the telecommunications infrastructure in the different states. In this regard, Escobar and Sámano (2018, p. 782) documented the leadership of northern states and Mexico City through indices (total, fixed and mobile), but a lag in southern and southeastern states of the country. Likewise, from the endowment of ICT goods and services at the household or individual level (proxy of the size of the telecommunications and digitization market) the result was not very different: lagging behind in southern states and leadership in Mexico City and northern states (Rodríguez, 2019).

These findings are important since they keep a close correspondence with the state competitiveness indices. The most recent results of the Mexican Institute for Competitiveness [IMCO] (2021) showed Mexico City, Nuevo León, Querétaro, Coahuila and Jalisco in the highly competitive group and in the very low category southern states such as Guerrero, Chiapas and Oaxaca. In the same sense, when using educational indicators (Secretaría de Educación Pública [SEP], 2021), in average level of schooling, Mexico City and four northern states (Nuevo León, Sonora, Coahuila and Baja California Sur) head the list; In terms of higher education coverage (of the total population between 18 and 23 years of age) the pattern is similar, with Mexico City, Sinaloa and Nuevo León standing out.

In addition to the above, Mexico presents a lag in coverage in higher education. By 2020, it reached 41.6% of the population group between 18 and 22 years of age (Presidency of the Republic, 2020); percentage that is reduced when taking into account the population that can be considered to have passed the university school stage, 25 to 34 years old, 23.6%, although still well below the average of the OECD countries (2019b), which is around 44.3%. . Likewise, the results of a survey on online education in Mexico by the Mexican Internet Association (AMIPCI, 2019) showed that 76% of Internet users were interested in studying; the main answers regarding the motivations for studying were because they wanted to increase their knowledge, improve their employment and due to the flexibility in study plans and schedules.

ICTs in Mexico have been established as a human right enshrined in Article 6 of the Constitution. Therefore, eliminating the digital gap is a great task today, a task that not only implies access to technology for less favored groups, but also teaching and training with the necessary skills for its use and management. And as part of this, the infrastructure and technological equipment available in higher education institutions also stand as an obstacle to overcome to move towards digital learning, as highlighted in the 2020-2024 Education Sector Program (SEP, 2020).

The literature review involved the search for research that addresses the use of ICT at different educational levels. In the case of primary education (basic or initial level), Tondeur, Braak and Valcke (2007), based on a questionnaire applied to 532 Dutch teachers and through a factorial analysis, found that the use of computers constitutes a tool information, learning and computer skills. Likewise, Aristovnik (2012, 2013) estimated the efficiency of the use of ICT in educational results with the help of a data envelopment analysis (DEA) and considered indicators such as the student-teacher ratio in secondary education, enrollment, the workforce with a high school education, and average scores on the 2006 Program for International Student Assessment (PISA) test. This analysis, focused on a set of 27 nations that are part of the European Union or that are members of the OECD (where the case of Mexico is excluded, due to being considered an atypical case), revealed that although the use of ICT is above the average for the set of countries studied (since estimated a relatively low technical efficiency in most of the countries considered), an increase in educational results or academic performance is required; This was particularly observed in developed countries such as the United States, the United Kingdom, and Austria.

Along this same line, Oyerinde and Bankole (2021) estimated the efficiency of investment in ICT infrastructure in a set of 51 countries grouped by income level, in the educational component of human development, based on a DEA. His analysis showed a close relationship between technical efficiency and economic income, for example, it was higher for nations with high economic income compared to that obtained for nations with medium income and, consequently, the latter showed a better performance compared to that achieved by low-income nations. under. Years ago, Oyerinde and Bankole (2019) themselves analyzed both the efficiency of investment and productivity on the use of ICT in the creation of public value, by carrying out a DEA and the estimation of the Malmquist index, respectively. , with information on the adult literacy rate in European countries, sub-Saharan Africa, Arab States and others. The evidence revealed an efficient use in terms of creating public value, although with an average loss of productivity; This last finding is related to variables such as the proportion of students from rural or remote regions (Carrington, Coelli and Rao, 2005) or the level of per capita income. (Agasisti, 2014).

In general, it was observed that the DEA and the Malmquist index have gained popularity in studying the performance of ICT use in terms of efficiency and productivity, respectively. However, the discussion in the literature has shown that in the absence of constant returns to scale, the Malmquist index does not measure the change in productivity (Grifell-Tatjé and Lovell, 1995), and may present infeasibility in its calculation (Kerstens and Van de Woestyne, 2014) and does not have a direct interpretation of total factor productivity (TFP) as a ratio of aggregate outputs and inputs (O'Donnell, 2010, 2012); such weaknesses can be circumvented with the estimation of the Hicks-Moorsteen index (HMTFP). Until now, for the analysis of the education sector, there is only a record of the work of Becerra and Santín (2021), who estimated the changes in productivity with the application of the HMTFP over time in the case of public spending on education. primary school in the Mexican states.

From the above, the following question arose: what has been the performance of the federal entities in the use of ICT in the main indicators of higher education in Mexico? Thus, the objective of this research was to empirically analyze the changes in total factor productivity (TCFP) through the use of ICT variables (inputs) and higher education variables (outputs). To verify this, the CPTF were estimated through the HMTFP with variable returns to scale and product orientation in a panel with annual information from the 32 states for the period 2010-2018. It is based on the hypothesis that states with a higher level of ICT penetration achieve better performance over time.

The justification for the selection of product and input variables is based on the argument of the neoclassical theory, AK model (Aghion and Howitt, 2009), whose interaction allows representing the technological progress required for the accumulation of intellectual capital or human capital through their combination with the accumulation of physical capital, essential to accelerate economic growth. Therefore, in this work the ICT variables are assumed as exogenous (input variables) and the educational ones as endogenous variables (product variables).

Derived from the above, it is important to mention the absence of literature that analyzes productivity and technical efficiency over time through educational and ICT indicators in Mexico; In contrast, the digital divide and the heterogeneity in the penetration of ICTs have been studied in great depth (at the national and international level) through the use of variables of access, use and skills in Internet management and by the endowment of assets. ICT (Escobar and Sámano, 2018; ITU, 2017; Rodríguez, 2019).

Under this scenario, this empirical analysis becomes relevant, where indicators of higher education and ICT infrastructure are related when estimating the HMTFP, which represents an innovative contribution to the field of study.

Method

Hicks–Moorsteen index

Following the seminal work of Jorgenson and Griliches (1967), here we consider the definition of TFP that is used in the analysis of decision-making units (DMUs), that is, as the ratio that exists between a product quantity index (higher education variables) and an input quantity index (ICT variables). From the previous conception, and that will be applied in this investigation, the index number that arises is a complete multiplicative index and is expressed as follows:

$$PTF_{nt} = \frac{Y_{nt}}{X_{nt}} \quad (1)$$

In said formula, PTF_{nt} represents the PTF of the nth DMU in the period t, y_{nt} y x_{nt} are the product (performance in higher education) and the aggregate input (endowment of ICT goods and services), respectively; so that TFP can be defined as the relationship between the growth of outputs and the growth of inputs. According to O'Donnell (2010, 2012), the HMTFP is consistent with definition (1), it is the only complete multiplicative index that can be estimated without price information, and it has a simultaneous output and input orientation.

The HMTFP is defined below:

$$HMTFP^{t,t+1} = \left[\frac{D_O^t(x_t,y_{t+1})D_O^{t+1}(x_{t+1},y_{t+1})}{D_O^t(x_t,y_t)D_O^{t+1}(x_{t+1},y_t)} \cdot \frac{D_I^t(x_t,y_t)D_I^{t+1}(x_t,y_{t+1})}{D_I^t(x_{t+1},y_t)D_I^{t+1}(x_{t+1},y_{t+1})}\right]^{1/2} \quad (2)$$

In this case, $D_O^t(x^t,y^t) = min\{\rho > 0: (x_i^t, y_i^t/\rho)\epsilon T^t\}$ represents the distance function of the products and $D_I^t(x^t,y^t) = max > 0: (x_i^t/\rho, y_i^t)\epsilon T^t\}$ represents the distance function of the inputs (Shephard, 1953). Both come from a reference technology $T^t = \{(x^t,y^t) \in R_+^m \times R_+^s: x^t\ produce\ y^t\}$, being the production frontier. The estimate of T^t is performed with an AED such as $\{(x^t, y^t \in R_+^m \times R_+^s \sum_{i=1}^n \lambda_i x_i^t \leq x^t, \sum_{i=1}^n \lambda_i y_i^t \geq y^t, \sum_{i=1}^n \lambda_i = 1, \lambda_i \geq 0)\}$ under the assumption of variable returns to scale (Banker, Charnes y Cooper, 1984) and how $\left\{\left(x^t, y^t \in R_+^m \times R_+^s \sum_{j=1}^n \lambda_j x_j^t \leq x^t, \sum_{j=1}^n \lambda_j y_j^t \geq y^t, \lambda_j \geq 0\right)\right\}$ under the assumption of constant returns to scale (Charnes, Cooper y Rhodes, 1978).

Interpretation of the HMTFP estimates indicate that a $HMTFP^{t,t+1} > 1$ reflects an increase or improvement in the productivity of the period t al $t+1$, and, conversely, a $HMTFP^{t,t+1} < 1$ represents a loss in productivity.

One of the main benefits of the HMTFP is the breakdown of the CPTF into two parts: a technology component and an efficiency component (O'Donnell, 2012). However, this research has only the objective of observing the aggregate behavior of the index and not the decomposition of the CPTF (which would require deepening theoretically in the technological and efficiency contribution, this exceeds the scope of this research); that is, it only focuses on analyzing the performance over time of a set of DMUs (the 32 Mexican states), as will be explained in the next section.

Data and variables

According to Bankole, Osei-Bryson and Brown (2013), ICT investment is made up of four elements: hardware, software, internal spending (investment in labor) and telecommunications. In the present investigation, the first two elements are considered as input variables: hardware when considering the availability of a computer at home and software when considering the availability of an Internet connection at home.

Likewise, and in agreement with the work of Bankole et al. (2011), the selection of the product variables is made based on the education component of the Human Development Index (IDH), to quantify productivity in the use of ICT over time based on the infrastructure available for their use and without considering the investments that are destined to them. In this sense, education is quantified as a reflection of educational achievements that are translated into the average level of schooling and educational coverage at the upper secondary and higher education levels, respectively.

Derived from the above, for the empirical analysis of the evolution of the CPTF of the use of ICT in higher education, a panel made up of the 32 states of Mexico with information for the period 2010-2018 was built. Five estimates of the HMTFP (hereinafter indices) were carried out, with different sets of products related to upper secondary and higher education (table 1), to analyze the different levels of productivity achieved when using the same set of inputs (ICT proxy) and observe the performance of Mexican states over time.

Table 1. Inputs and outputs for the estimation of the HMTFP

Índice	Insumos	Productos
I	Hogares con conexión a internet	Grado promedio de escolaridad
	Computadora en el hogar	
II	Hogares con conexión a internet	Grado promedio de escolaridad
	Computadora en el hogar	Porcentaje de cobertura en educación media superior (15-17 años)
		Porcentaje de cobertura educación superior (18-23 años, incluye posgrado)
III	Hogares con conexión a internet	Grado promedio de escolaridad
	Computadora en el hogar	Porcentaje de la matrícula en educación media superior
		Porcentaje de la matrícula en educación superior
IV	Hogares con conexión a internet	Porcentaje de la matrícula en educación media superior
	Computadora en el hogar	Porcentaje de la matrícula en educación superior
		Razón profesor por cada 100 estudiantes en educación media superior
		Razón profesor por cada 100 estudiantes en educación superior
V	Hogares con conexión a internet	Grado promedio de escolaridad
	Computadora en el hogar	Porcentaje de la matrícula en educación media superior
		Porcentaje de la matrícula en educación superior
		Razón profesor por cada 100 estudiantes en educación media superior
		Razón profesor por cada 100 estudiantes en educación superior

Source: self made

A continuación, se enlistan las variables que se emplearon como insumos para la estimación de los HMTPF para cada una de las entidades federativas.

- Hogares con conexión a internet (valor en escala de 0 a 1): respuesta afirmativa a la pregunta de si disponen en el hogar de conexión a internet en el hogar; 2010 a 2014, por medio del Módulo sobre Disponibilidad y Uso de Tecnologías de la Información en los Hogares (Modutih) (Instituto Nacional de Estadística y Geografía [Inegi], 2010, 2011, 2012, 2013, 2014); y de 2015 a 2018, a través de la Encuesta Nacional sobre Disponibilidad y Uso de Tecnologías de la Información en los Hogares (Endutih) (Inegi, 2015, 2016, 2017, 2018).
- Computadora en el hogar (valor en escala de 0 a 1): respuesta afirmativa a la pregunta de si Disponen en el hogar de computadora: 2010-2014, en condiciones de uso en los últimos 12 meses (Modutih [Inegi, 2010, 2011, 2012, 2013, 2014]); y de 2015-2018, computadora de escritorio o portátil (teclado, monitor y CPU, separados o integrados, respectivamente) (Endutih [Inegi, 2015, 2016, 2017, 2018]).

Se enlistan las variables que se emplearon como productos para la estimación de los HMTPF para cada una de las entidades federativas.

- Grado promedio de escolaridad (iniciando por primaria hasta doctorado): se refiere a la cantidad promedio de grados escolares aprobados por la población de 15 años y más del país. Las cifras fueron obtenidas de la Dirección General de Planeación, Programación y Estadística Educativa (DGPPyEE) de la SEP (2021).
- Porcentaje de cobertura en educación media superior (jóvenes de 15-17 años): es la proporción de la matrícula total de educación media superior respecto a la población de 15 a 17 años, edad oficial para cursar este nivel (también se le conoce como *demanda natural*). Las cifras fueron obtenidas de la DGPPyEE de la SEP (2021).
- Porcentaje de cobertura educación superior (18-23 años): corresponde al porcentaje de la matrícula total del nivel técnico superior universitario, licenciatura y posgrado en la modalidad escolarizada respecto al total de población de 18 a 23 años. Las cifras fueron obtenidas de la DGPPyEE de la SEP (2021).
- Porcentaje de la matrícula en educación media superior: se calcula al dividir la matrícula de nivel medio superior entre el total de estudiantes del sector educativo. Las cifras fueron obtenidas de la DGPPyEE (SEP, 2018).

- Porcentaje de la matrícula en educación superior: se calcula al dividir la matrícula de nivel superior entre el total de estudiantes del sector educativo. Las cifras fueron obtenidas de la DGPPyEE (SEP, 2018).
- Razón de cantidad de profesores por cada 100 estudiantes en educación media superior: se calcula al dividir el número total de docentes que atienden en nivel medio superior entre la matrícula total en el mismo nivel educativo, posteriormente es multiplicado por 100. Las cifras de profesores y matrícula fueron obtenidas de la DGPPyEE (SEP, 2018).
- Razón de cantidad de profesores por cada 100 estudiantes en educación superior: se calcula al dividir el número total de docentes que atienden en nivel superior entre la matrícula total en el mismo nivel educativo, posteriormente el resultado es multiplicado por 100. Las cifras de profesores y matrícula fueron obtenidas de la DGPPyEE (SEP, 2018).

Tabla 2. Estadística descriptiva: insumos y productos (2010 a 2018)

Variable	Media	Desviación estándar (DE)	Mín.	Máx.
Hogares con internet	0.35	0.17	0.05	0.83
Computadora	0.33	0.10	0.12	0.60
Escolaridad	9.02	0.85	6.67	11.18
Cobertura superior	27.03	8.81	12.26	71.94
Cobertura media superior	71.66	10.70	49.66	121.10
Matrícula media superior (%)	0.13	0.01	0.10	0.17
Matrícula superior (%)	0.09	0.02	0.04	0.18
Profesor / 100 estudiantes media superior	7.76	1.41	4.66	11.36
Profesor / 100 estudiantes superior	9.43	1.56	6.23	13.26

Source: self made

Por la naturaleza del objetivo de este trabajo, la estadística descriptiva mostrada en la tabla 2 no arroja información respecto a las tendencias o comportamiento de los indicadores (en conjunto o para cada uno de los estados) a lo largo del periodo analizado. Lo que sí destaca es un mayor incremento global en el porcentaje promedio de hogares con internet, por encima del indicador de Computadora. En cuanto a los indicadores educativos, resalta el avance importante en el indicador de cobertura en educación media superior; el de cobertura en educación superior presenta un rezago importante, cuyo valor a nivel nacional alcanza apenas alcanzaba 40 % (Presidencia de la República, 2020), muy por debajo del que presentan los países miembros de la OCDE (50 %).

Se observa que a lo largo del periodo de análisis se tiene una escolaridad (población de 15 años y más) promedio de 9.02 años, lo cual significa que se tiene concluida la educación secundaria. La escolaridad mínima se ubica en 6.67, lo que se interpreta como poco más de la educación primaria concluida, mientras que la escolaridad máxima se estima en 11.18, esto es, el nivel medio superior.

La razón de profesores por cada 100 estudiantes de educación media superior, en promedio y para el periodo analizado, se ubica en 7.76, mientras que la misma razón en el caso de la educación superior se estima en 9.43. Ello denota una matrícula más amplia en la educación media superior que en la educación superior en México (más de 1 millón de estudiantes, aproximadamente). Lo anterior tiene estrecha relación con la media de la razón profesor por cada 100 estudiantes en educación media superior (7.76), que resulta ligeramente inferior en comparación con la misma razón observada en el caso de la educación superior (9.43).

Resultados

En esta investigación se analizó el desempeño de las 32 entidades federativas de México a lo largo de ocho años, de 2010 a 2018, a través de la estimación del HMTFP que asume retornos variables a escala. La interpretación de los resultados de los CPTF se realizó bajo el siguiente criterio. Como se ha mencionado en la sección anterior, los valores mayores (menores) a la unidad reflejan una ganancia (pérdida) en los CPTF de cada entidad federativa de un periodo a otro.

Una vez estimados los cinco índices de HMTFP se observó que, en conjunto, a lo largo del periodo de análisis 2010-2018 (tabla 3), se presentaron pérdidas en la productividad que oscilaron entre -3.29 % (índice IV) y -5.09 % (índices I y II) en promedio. Los índices I, II y III presentaron resultados promedio similares en el HMTFP estimado. Se observó el mejor desempeño durante el periodo 2010 a 2011 con CPTF que oscilan entre 11.33 % y 11.77 %. Asimismo, en conjunto, el comportamiento de las entidades federativas mostró tres años consecutivos de pérdida de productividad (2011-2014), la mayor fue observada de 2013 a 2014, con CPTF de entre -20.33 % y -20.44 % (tabla 3).

Tabla 3. HMTFP promedio por periodo (2010-2018)

HMTFP	Índice				
Periodo	I	II	III	IV	V
2010-2011	1.1177	1.1163	1.1133	1.0931	1.0972
2011-2012	0.9682	0.9717	0.9703	0.9549	0.9531
2012-2013	0.9148	0.9118	0.9187	1.0169	1.0093
2013-2014	0.7956	0.7967	0.7966	0.8036	0.7990
2014-2015	1.0249	1.0212	1.0197	0.9872	0.9892
2015-2016	0.9948	0.9893	0.9863	0.9395	0.9437
2016-2017	0.9693	0.9704	0.9706	0.9717	0.9686
2017-2018	0.9882	0.9869	0.9895	0.9845	0.9856
Media	*0.9491*	*0.9491*	*0.9497*	*0.9671*	*0.9647*

Source: self made

On the other hand, the average results observed in the IV and V indices are not too far from the previous indices, however, they quantify an increase in the CPTF from 2012 to 2013 with a productivity gain of 1.69% and 0.93%, respectively, to difference from what is quantified in indices I, II and III, where a loss of productivity of between -8.13% and -8.82% is obtained.

Table 4 shows the average estimates of the HMTFP made by federal entity (DMU) according to each of the indices during the study period 2010 to 2018. From the results of index I, which includes the average level of schooling as the only product, the state of Veracruz was highlighted as the only federal entity that has presented a slight gain in average productivity, of just 0.31%. On the contrary, the highest average productivity losses were observed in Tlaxcala (-14.56%), Oaxaca (-9.76%), Tabasco (-8.41%), Guanajuato (-8.31%) and Chihuahua (-8.22%).

From the analysis of the estimates of index II (table 4), where the percentages of coverage in upper secondary education and higher education were integrated into the list of products, Hidalgo and Veracruz stood out with average positive CPTF of 1.63% and 0.68%, respectively. While the largest negative average CPTF occurred in Tlaxcala (-13.82%), Nayarit (-10.28%), Oaxaca (-9.76%), Tabasco (-9.57%) and Guanajuato (-8.31%).

In index III, when integrating the enrollment percentages in upper secondary and higher education as products, Veracruz and Hidalgo once again stood out as the states with the best average performance, with CPTF of 1.51% and 0.98%, respectively (table 4). . The lowest performances were presented in Tlaxcala (-14.22%), Tabasco (-10.33%), Oaxaca (-9.80%), Nayarit (-9.03%) and Guanajuato (-8.27%) with the highest negative average CPTF.

Table 4. Average HMTFP by state (2010-2018)

DMU	Entidad	Índice I		Índice II		Índice III		Índice IV		Índice V	
		HMTFP	#	HMTFP	#	HMTFP	#	HMTFP	#	HMTFP	#
1	Aguascalientes	0.9265	24	0.9265	26	0.9266	24	0.9427	23	0.9505	22
2	Baja California	0.9727	8	0.9727	6	0.9856	4	1.0056	4	0.9898	7
3	Baja California Sur	0.9524	15	0.9473	19	0.9529	18	0.9762	13	0.9757	12
4	Campeche	0.9803	5	0.9681	10	0.9678	10	1.0029	6	0.9973	4
5	Coahuila	0.9698	9	0.9697	8	0.9698	9	0.9939	7	0.9947	5
6	Colima	0.9516	16	0.9516	18	0.9352	20	0.9695	15	0.9685	15
7	Chiapas	0.9243	26	0.9297	23	0.9253	25	0.9326	28	0.9326	27
8	Chihuahua	0.9178	28	0.9238	27	0.9235	27	0.9619	17	0.9576	19
9	Ciudad de México	0.9461	19	0.9706	7	0.9598	14	0.9610	19	0.9610	18
10	Durango	0.9426	20	0.9405	20	0.9611	12	0.9890	8	0.9858	9
11	Guanajuato	0.9170	29	0.9170	28	0.9173	28	0.9415	24	0.9456	23
12	Guerrero	0.9263	25	0.9280	25	0.9245	26	0.9399	25	0.9298	28
13	Hidalgo	0.9969	2	1.0163	1	1.0098	2	1.0295	1	1.0284	1
14	Jalisco	0.9329	23	0.9329	21	0.9320	23	0.9796	11	0.9760	11
15	Estado de México	0.9664	11	0.9664	11	0.9664	11	0.9838	10	0.9823	10
16	Michoacán	0.9772	6	0.9621	13	0.9740	7	0.9263	30	0.9262	30
17	Morelos	0.9686	10	0.9686	9	0.9710	8	0.9599	20	0.9563	20
18	Nayarit	0.9183	27	0.8972	31	0.9098	29	0.9555	21	0.9347	26
19	Nuevo León	0.9580	13	0.9580	15	0.9580	16	1.0030	5	0.9736	13
20	Oaxaca	0.9024	31	0.9024	30	0.9020	30	0.9346	27	0.9349	25
21	Puebla	0.9381	21	0.9318	22	0.9336	22	0.9234	31	0.9231	31
22	Querétaro	0.9658	12	0.9659	12	0.9601	13	0.9497	22	0.9514	21
23	Quintana Roo	0.9849	4	0.9849	4	0.9856	5	0.9768	12	0.9942	6
24	San Luis Potosí	0.9556	14	0.9595	14	0.9593	15	0.9645	16	0.9705	14
25	Sinaloa	0.9476	18	0.9541	16	0.9498	19	0.9721	14	0.9661	16

26	Sonora	0.9962	3	0.9962	3	0.9959	3	1.0266	3	1.0206	3
27	Tabasco	0.9159	30	0.9043	29	0.8967	31	0.9297	29	0.9297	29
28	Tamaulipas	0.9763	7	0.9763	5	0.9756	6	1.0284	2	1.0267	2
29	Tlaxcala	0.8545	32	0.8618	32	0.8578	32	0.9039	32	0.9034	32
30	Veracruz	1.0031	1	1.0068	2	1.0151	1	0.9864	9	0.9863	8
31	Yucatán	0.9505	17	0.9521	17	0.9558	17	0.9611	18	0.9611	17
32	Zacatecas	0.9343	22	0.9294	24	0.9339	21	0.9364	26	0.9352	24
	Media	*0.9491*		*0.9491*		*0.9497*		*0.9671*		*0.9647*	

Note: # Indicates the position in the ranking

Source: self made

The estimates obtained in the IV index, which excluded the average level of schooling from the list of products and integrated the teacher ratios per 100 students in upper secondary and higher education, respectively, showed that 6 of the 32 states have achieved CPTF positive average. Hidalgo (2.95%), Tamaulipas (2.84%), Sonora (2.65%), Baja California (0.56%), Nuevo León (0.30%) and Campeche (0.29%) stood out with the highest productivity gains. On the other hand, the greatest productivity losses occurred in Tlaxcala (-9.61%), Puebla (-7.66%), Michoacán (-7.37%), Tabasco (-7.03%) and Chiapas (-6.74%).

Finally, in the estimates of the V index, the average level of schooling was added to the products of the IV index, so that Hidalgo (2.84%), Tamaulipas (2.67%) and Sonora (2.06%) stood out with average positive CPTF. The rest of the states presented negative average CPTF, Tlaxcala (-9.67%), Puebla (-7.70%), Michoacán (-7.38%), Tabasco (-7.04%) and Guerrero (-7.02%) stand out with the highest losses of productivity.

Discussion

The improvement in the index from 2013 to 2014 (table 3), for example, corresponds to the year after the implementation of the National Digital Strategy (2013), during the previous federal administration (2012-2018), a strategy of which two stood out. key enablers: connectivity and inclusion and digital skills (Government of the Republic, 2013). Among the main actions, the goal was to provide connectivity to 250,000 public places by 2018 through the México Conectado project, an instrument to promote digitization and greater use and exploitation of the Internet, however, it was rescheduled to 150,000 public sites and was later reduced to 101,000 (Castañares, 2017).

In general, it was expected that those states with a greater endowment of ICTs would achieve the best performance over time, and this behavior was fulfilled in the cases of Baja California, Nuevo León and Sonora according to the endowment of households with Internet and of computer at home, according to the results of the IV and V indices (Table 4).

On the contrary, Hidalgo, which stands out for its good performance in the first position in the indexes II, IV and V and in the second in the indexes I and III, and Veracruz, which was located in the first position in the indexes I and II and in the second position in the III index, were states that with low endowments of inputs (in the last quartile of the set) have made good use of these in terms of productivity in higher education.

The performance of Mexico City and Baja California Sur must be highlighted, states that did not occupy the first positions in the estimated indices despite being the states with the largest amount of both inputs during the analysis period; A similar behavior was observed in states such as Aguascalientes, Colima, and Jalisco, which, in general, ranked below position 14 according to the HMTFP estimates (Table 4).

Although the issuance of the Federal Telecommunications and Broadcasting Law and the creation of the Federal Electoral Institute of Telecommunications in 2014 support the rights and contribute to compliance with the constitutional mandate of universal coverage of broadband internet access in public spaces (Jiménez, 2017), according to the aggregate results of the Mexican states, an insufficient effort was observed on the part of the federal government in targeting connectivity programs, especially in the case of higher education.

The implementation of the National Digital Strategy, of the e-Mexico National System as part of the México Conectado project and the parallel project of Punto México Conectado in 2015 oriented efforts to provide digital skills courses in all federal entities aimed at the population in general and provide internet access in schools and public places with the aim of contributing to the digitization of the country. Despite this, the budget cuts and the reduction of the original goals of the plans have not allowed the expected results to be achieved.

In addition to the above, there has been a tendency to prioritize basic education during the implementation of public programs and policies, such is the case of Enciclomedia in 2004 with the digitization of textbooks and the use of multimedia resources; the Digital Skills for All program between 2009 and 2012 with telematic classrooms, and the @prende2.0 project between 2012 and 2018 that included the “Laptops for children in 5th and 6th grades” program and the program of Inclusion and Digital Literacy (Arredondo, 2020).

According to Endutih figures, throughout the period analyzed an increase in the availability of ICTs (accessibility and use) was glimpsed. However, an unsupervised and unfocused use in higher education was perceived which, together with the lack of digital skills of teachers and students, led to a decline in the quality and equality of education (Hinostroza, 2018), a situation that was also reflected in the performance indicators in the use of technology and communication inputs, as shown by the results of the HMTFP estimates in this research.

Finally, it has been highlighted that the patterns of ICT use in educational centers depend on the context and temporality (Tondeur et al., 2007), as well as the educational level. In the literature, it has been observed that it is at the higher levels where there is a greater propensity to create environments and provide greater possibilities for the implementation and use of ICTs according to the development of study plans within the classroom by teachers. .

There were some limitations in this research. The period of analysis was narrowed from 2010 to 2018, at least one year prior to the start of the 2019 coronavirus disease (covid-19) pandemic state in the international context, with which some progress in coverage could have been observed. and access to higher education through the implementation of mixed learning models derived from the reduction in the use of physical spaces in Mexico. Another limitation consisted of the lack of detailed information on the public spending that was invested in ICT at the state level, with which said variable could not be included in the set of products for the estimation of the different indices; Nor was there any detail on public spending on investment and development (R&D) that could serve as a proxy for public spending invested in ICT by the federal entities.

Conclusions

Empirical evidence showed that productivity in the use of ICT when taking into account the results of the education sector varies among the states of Mexico. In this sense, this empirical analysis becomes relevant, where indicators of higher education and technological infrastructure are related to those of ICT, through the application of the HMTFP, which represents an innovative contribution to the field of study.

The analysis of changes in productivity over time showed that most of the states presented losses in productivity during the period 2010-2018. Likewise, the estimates indicated that the states of Veracruz and Hidalgo maintained a positive average change in productivity throughout the study period, when the average level of schooling and the percentages of coverage in upper secondary education and higher. The results also indicated that when products such as enrollment percentages in upper secondary and higher education are incorporated, as well as the teacher ratios per 100 students in upper secondary and higher education, the number of states with average positive changes increased. among them Hidalgo, Tamaulipas, Sonora, Baja California, Nuevo León and Campeche.

In general, those states with the largest ICT endowments were expected to achieve the best performance over time. Said affirmation was fulfilled in the cases of Baja California, Nuevo León and Sonora, according to the endowment of homes with Internet and a computer in the home (indices IV and V), which have maintained leadership in the adoption of ICTs in the considered period. On the contrary, Veracruz and Hidalgo, which were located in the first positions, were states that with low endowments of inputs (last quartile of the set) have achieved the best use of these in terms of productivity in higher education.

Likewise, it is highlighted that given the gradual increase in the availability and use of ICT inside and outside the educational environment (not supervised or focused on higher education), together with the lack of digital skills of teachers and students, it is possible to put the quality and equality of education is at risk, in addition to achieving low performance indicators.

Despite the limitations indicated in advance, we consider it imperative to carry out this type of analysis on public performance, especially within the education sector, in order to have evidence of the evolution of public performance. Likewise, we believe that an improvement in the productivity of the use of ICT can contribute significantly to a greater development and growth of the federal entities, for which it is imperative to have public policies that articulate both investment in ICT and its implementation in the sector. education at its different levels to generate and reinforce skills in the formation of human capital.

Future lines of research

As previously mentioned, the present empirical analysis linking higher education and ICT infrastructure indicators when estimating the HMTFP represents an innovative contribution to the field of study. In the future, variables that account for the quality of education should be incorporated into the analysis, such as the case of the results of standardized tests or the failure rate for upper secondary and higher education; This can account for the relevance of the educational function for economic and social development.

It is suggested to integrate into the analysis the spending that is invested in ICT infrastructure, or the spending on R&D, which can be taken as a proxy for the spending allocated to ICT infrastructure, to be considered as an input variable in the estimation of the PTF.

Likewise, it has been concluded that an extension of the analysis of productivity within the countries is feasible, this by considering the subnational levels as units of analysis, although this depends on the availability of disaggregated information. This could provide complementary results to the study of the performance of central administrations, contribute to broadening the discussion of results and achieve more solid reflections within the performance of comparisons at a national level.

The foregoing can help reinforce the design of public policies, in the understanding of contributing to the generation of timely statistics and indicators for decision-making based on empirical evidence, in addition to the identification of good practices and their replication to reach a improvement in public performance.

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