Analysis of productivity in the Health Care Centers of the Community of Madrid (Spain) 2015-2017

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ABSTRACT

The main objective of this work has focused on extending the existing literature on the analysis of total factor productivity of the Health Care Centers (HCC) of the Community of Madrid (Spain) in the period 2015-2017, with two important contributions; the application and comparison of the Malmquist indices with two robust methodologies such as the Hicks-Moorsteen and Färe Primont indices which, except for error, have not been previously used in this sector and the regional scope, which has been scarcely analyzed. The main results reveal decreases in HC productivity due to the three proposed methodologies. These decreases range between 4.90% and 0.25% for the Färe-Primont and Hicks-Moorsteen indices respectively between 2015/17 in average terms. Convergence analyses confirm that this takes place in the case of the Malmquist and Hicks-Moorsteen proposals.

Análisis de la productividad en los Centros Sanitarios de la Comunidad de Madrid (España) 2015-2017

RESUMEN

El objetivo principal de este trabajo se ha enfocado en extender la literatura existente sobre el análisis de la productividad total de los factores, de los Centros Sanitarios de la Comunidad de Madrid en el periodo 2015-2017, con dos importantes contribuciones, la aplicación y comparación de los índices de Malmquist con dos metodologías robustas, los índices de Hicks-Moorsteen y Färe Primont que salvo error no han sido previamente utilizadas en este sector y el ámbito regional, que ha sido escasamente analizado. Los principales resultados revelan disminuciones de la productividad de los CS por las tres metodologías propuestas. Estas disminuciones oscilan entre 4.90% y 0.25% para los índices de Färe-Primont y de Hicks-Moorsteen respectivamente entre 2015/17 en términos medios. Los análisis de convergencia confirman que esta tiene lugar en el caso de las propuestas de Malmquist y Hicks-Moorsteen.

1. Introduction.

Spain's healthcare system ranks third in the world, between 200 countries behind Hong Kong and Singapore in terms of efficiency (Vieira, 2018). To hold this position suggests that the Spanish Health System (hereinafter SHS), in particular, manages its resources under criteria of maximizing the quantity and quality of health (Romano & Choi, 2016).

The competitive situation of the SHS is a challenge, considering the economic crisis and consequent budget cuts and political decisions on welfare (Mateos & Penedés, 2013). As mentioned, Segura (2014) the restrictive measures carried out in terms of welfare and health policies, could have had negative consequences on public health management. In this sense, the media have reflected the current state of the SHS. For example, Flores (2019) addresses the lack of investment in technological renewal and innovation and its erosion in the SHS. It is surprising that, on the one hand, Spain is among the most efficient countries and, at the same time, ranks 18th out of the 35 OECD countries in terms of public health expenditure. In addition, Spain allocates 6.3% of GDP, far from 7.6%, 9.5% and 9.6% from United Kingdom, France, and Germany respectively.

Regarding the Health Care Centers (hereinafter HCC) within SHS, as mentioned García-Latorre et al. (1996) these resemble multi-product organizations where the objective to be fulfilled is the maximization of social efficiency, bearing in mind the criterion of "equity". The analysis of efficiency and productivity in the SHS has received significant attention, as evidenced by the proliferation of studies in recent years. Authors such as Pelone et al. (2015), Barnum et al. (2016) or Vafaee et al. (2018), conduct interesting reviews of international literature on the presence of non-parametric DEA methodologies in the health sector. Likewise, these authors collect the use of output and input variables, as well as the units of analysis used. In relation to the HCC, they have been studied at a national level, among others by García-Latorre et al. (1996) in Aragón (Zaragoza), Puig-Junoy (2000) in Aragón (Zaragoza), Huesca, Navarra and Cataluña, Cordero-Ferrera et al. (2011) in Extremadura, Cordero-Ferrera et al. (2016) in País Vasco, and Romano and Choi (2016) in Cataluña (Barcelona).

In this context, this work focuses its spatial scope on the Community of Madrid, using the HCCs as analysis, in the period 2015-2017. The main objective is to extend the existing literature on the analysis of total factor productivity (hereinafter TFP) with two important contributions: 1) The application and comparison of the Malmquist index (hereinafter MALM), with two robust methodologies using the TFP index, Hicks-Moorsteen (hereinafter HMTFPC) & Färe Primont (FPTFPC), which except for errors have not been previously used in this sector; 2) The regional level, which has been scarcely analyzed. In addition, measures of quality of care are incorporated into the analysis.

The work is organized in the following way. In Section 2, the data and methodology are presented. Section 3 shows the results. The fourth section presents the main conclusions.

2. Data and methodologies.

2.1. Data.

The outputs and inputs have been obtained from the Observatory of the Madrid Health Service (http://observatorioresultados.sanidadmadrid.org/AtencionPrimariaLista.aspx) and supported by literature (see Cordero et al., 2016). Specifically, the outputs include overall customer satisfaction, morbidity, and avoidable hospitalization as a percentage. These two variables have been calculated as a distribution proportional to each HCC, since the values were assigned to the hospitals belonging to them. The inputs in physical or economic units are the health personnel and the overall pharmaceutical expenditure per user. Table 1 shows the descriptive statistics.

Table 1. Descriptive statistics.

Variable	2015-2017	
	Mean	SD
Customer satisfaction (%)	0.9029	0.0471
Morbidity (%)	0.7317	0.0004
Avoidable hospitalization (%)	0.0107	0.0078
Health personnel (N. of professionals)	32.689	12.279
Pharmaceutical expenditure per user euros)	11.308	0.6610

Source: Prepared by the authors based on the Observatory of the Health Service of Madrid.

2.2. Methodologies.

As mention Martinez-Cillero and Thorne (2019), the MALM was initially proposed in the influential article by Caves, Christensen and Diewert (1982), and several authors have provided decompositions of TFP based on this index (Färe et al., 1994; Balk, 2001; Lovell, 2003). Although MALM is widely applied, it faces two important limitations. First, the MALM is not multiplicatively complete since it cannot be expressed as a relationship between a MALM output quantity index and a MALM (O'Donnell, 2008). Because of this, O'Donnell (2008) suggests that it cannot be satisfactorily broken down into significant technical changes, efficiency changes or scale efficiency change components. Second, the MALM does not satisfy transitivity (O'Donnell, 2011). In this sense, authors such as Russell (2018) mention that when comparing the MALM and HMTFPC (or FPTFPC) indexes, the former is a measure of technological change (change in the production frontier) while the latter is a (broader) measure of change in TFP (incorporating the effects of movement along the frontier as well as change in the same) (Grifell-Tatjé & Lovell, 1995).

In this paper, in line with O´Donnell (2011) to avoid any restrictive and empirically proven assumptions about the technology, the MALM, HMTFPC and FPTFPC indexes are estimated using VRS LPs that allow both technical progress and regression. According to this author, the mathematical approach of these three indexes is the one included in Table 2, where q, x, t, s are the quantities of output, input, and time references respectively (for further details see O´Donnell, 2011).

<p style="text-align:center">**Table 2. Productivity index for multilateral and multi-temporal comparisons.**</p>

	Malmquist	Hicks-Moorsteen	Färe-Primont
Output aggregator Function	$Q(q)= D_o (x_{it}, q, t)$ [Eq 1.1]	$Q(q)=[D_o(x_{hs}, q, s)D_o(x_{it}, q, t)]^{1/2}$ [Eq 1.2]	$Q(q)= D_o (x_o, q, t_o)$ [Eq 1.3]
Intput aggregator function	$X(x) = D_i (x, q_{it}, t)$ [Eq 2.1]	$X(x)=[D_I (x, q_{hs}, s)D_I (x, q_{it}, t)]^{1/2}$ [Eq 2.2]	$X(x) = D_I (x, q_o, t_o)$ [Eq 2.3]
Productivity Index	$MFP_{hs,\ it} =$ $\dfrac{D_o (x_{it},q_{it},t)}{D_o (x_{it},q_{hs},t)} \dfrac{D_I (x_{hs},q_{it},t)}{D_I (x_{it},q_{it},t)}$ [Eq 3.1]	$MFP_{hs,it} =$ $\left[\dfrac{D_o (x_{hs},q_{it},s)}{D_o (x_{hs},q_{hs},s)} \dfrac{D_o (x_{it},q_{it},t)}{D_o (x_{it},q_{hs},t)}\right.$ $\left.\dfrac{D_I (x_{hs},q_{hs},s)}{D_I (x_{it},q_{hs},s)} \dfrac{D_I (x_{hs},q_{it},t)}{D_I (x_{it},q_{it},t)}\right]^{1/2}$ [Eq 3.2]	$MFP_{hs,\ it} =$ $\dfrac{D_o (x_o,q_{it},t_o)}{D_o (x_o,q_{hs},t_o)} \dfrac{D_I (x_{hs},q_o,t_o)}{D_I (x_{it},q_o,t_o)}$ [Eq 3.3]

Source: O´Donnell (2011).

2.3. Comparison of productivity distributions and Convergence.

Comparison of productivity index distributions will be performed using the Kolmogorov-Smirnov test (KS) (and the graphical function of distributions) and kernel density functions. Finally, a classical convergence regression analysis will be applied, together with a dynamic convergence analysis by means of stochastic kernels.

As suggested by Delgado and Fariñas (2002), the application of the KS test allows us to test the stochastic dominance among the empirical distributions of the HC groups being compared. F and G denote the cumulative distribution functions associated with the normalized efficiency corresponding to two groups of HCC to be compared. The stochastic domination of G over F implies that $F(x) \geq G(x) \ \forall \ x \ \epsilon \ \Re$ with strict inequality for some x. The KS test is appropriate in this case, as it does not require a specific distribution family. The KS test of stochastic domination of G over F can be formulated as:

$$H0: F(x) - G(x) \geq 0 \ \forall \ x \ \epsilon \ \Re < \text{versus} \tag{4}$$

$$H1: F(x) - G(x) < 0 \ \forall \ x \ \epsilon \ \Re$$

To obtain more complete results, the convergence processes will be analyzed in two different ways, for HCC. Firstly, the proposal of the classic of β-convergence Barro and Sala-i-Marti (1992) will be used. This approach is based on analyzing the trend of HCC with relatively low initial levels of TFP to grow relatively faster than the remaining HCC.

The regression proposed in equation 5 (HMTFPC, MALM, FPTFPC), allows to determine the mentioned process, observing the negative sign and the statistical significance of the parameter β.

$$Ln \sum_{t=1}^{T-1} \left(\frac{1}{T-1} \right) \left(\frac{\text{HMTFPC}_i^{t+1}}{\text{HMTFPC}_i^t} \right) = \alpha + \beta Ln\text{HMTFPC}_i^t + \varepsilon_i \tag{5}$$

where HMTFPC_i^t (or MALM, FPTFPC) & HMTFPC_i^{t+1} is the productivity index in 2015/16 and 2015/17 respectively. β is the parameter to estimate to measure the convergence process.

The classical convergence analysis proposed above is sufficiently informative. However, some authors such as Quah (1997) mention some drawbacks in using this type of methodology due to the lack of information about the internal dynamics of the distribution, since it only picks up some moments of it. In this sense, the use of kernel density functions is usually the most common, to visualize the external form of the distribution. Since efficiency distributions are not normal, the application of these functions makes it possible to avoid important features that might arise. The non-parametric approach, which will be shown below, requires choosing a method to smooth the data. The chosen method is usually kernel smoothing (Scott, 1992).

To capture intradistributional changes or movements, transition matrices could be applied. However, this methodology implies that the results depend on the number and amplitude of the intervals considered. For this reason, authors such as Quah (1997), Stokey and Lucas (1989), prefer to analyze the dynamics within the distribution by means of a continuous approximation based on the use of stochastic kernels, which are nothing more than the equivalent of a transition matrix with a number of intervals that tends to infinity. It is therefore a graphic way of observing the changes, which will also be presented in Section 3.

3. Results.

This section shows the results obtained by applying the three techniques included in the methodologies section. Initially, the average and median values of the output and input variations are presented, as well as the productivity indexes and their components, as reflected in Table 3. Subsequently, comparative analyses of the distributions of the productivity indexes are performed. Finally, the convergence analysis is carried out.

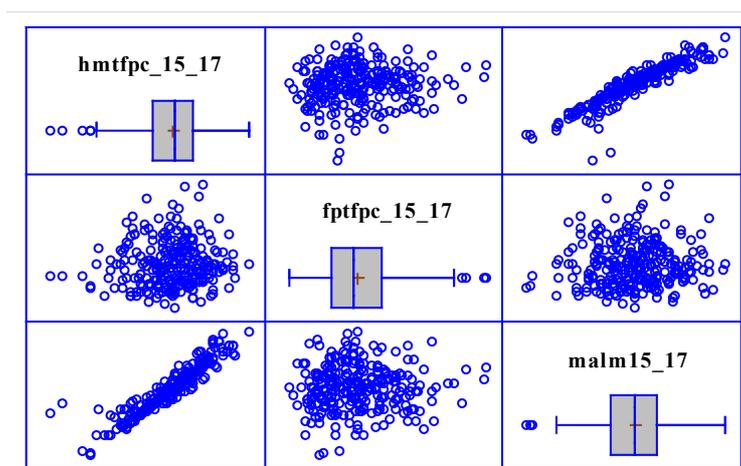**Table 3. Results of the Malmquist, Hicks-Moorsteen & Färe-Primont indexes.**

Component	Period	Malmquist			Hicks-Moorsteen			Färe-Primon		
		Median	Mean	SD	Median	Mean	SD	Median	Mean	SD
Output change	2015/2016	1.0000	0.9989	0.0068	1.0003	1.0025	0.0143	0.9961	0.9944	0.0077
	2015/2017	1.0000	0.9998	0.0055	1.0005	1.0000	0.0223	0.9961	0.9944	0.0074
Input change	2015/2016	1.0000	1.0000	0.0010	1.0103	1.0102	0.0131	1.0484	1.0430	0.0603
	2015/2017	1.0000	1.0000	0.0004	1.0025	1.0026	0.0118	1.0507	1.0457	0.0610
MALM/HMTFPC/FP	2015/2016	0.9908	0.9918	0.0172	0.9903	0.9924	0.0197	0.9497	0.9534	0.0568
	2015/2017	1.0003	1.0000	0.0226	1.0001	0.9974	0.0252	0.9459	0.9510	0.0573
Techn. change	2015/2016	0.9782	0.9772	0.0099	0.9785	0.9787	0.0113	0.9869	0.9869	0.0000
	2015/2017	1.0064	1.0057	0.0080	1.0075	1.0038	0.0130	0.9902	0.9902	0.0000
Efficiency change	2015/2016	1.0138	1.0149	0.0206	1.0103	1.0140	0.0256	0.9624	0.9661	0.0576
	2015/2017	0.9943	0.9943	0.0239	0.9957	0.9937	0.0279	0.9552	0.9604	0.0579

Source: Own elaboration.

Rows 1 and 2 show the output variations, while rows 3 and 4 show the input variations. Rows 5 and 6 show the values of the MALM, HMTFPC and FPTFPC index. In general, the values of the productivity index show levels lower than 1, for the two subperiods. In the case of MALM and HMTFPC there is a timid growth in the case of the median. These results take place, before generally positive variations of the inputs (rows 3 and 4) for HMTFPC and FPTFPC and increases in the outputs (rows 1 and 2) for HMTFPC and decreases for FPTFPC. Productivity decreases are a consequence of both TECHCH and EFFCH, as shown in rows 7 to 10. The FPTFPC methodology shows the greatest deterioration in productivity.

Figure 1 shows the spatial distribution of the ranking of the 25 top HCC (black dots) analyzed according to FPTFPC and HMTFPC parts left and right respectively. There are no coincidences in the hierarchical order of the productivity levels of the two methodologies. Figure 2 and Table 3 show the correlation between the MALM and HMTFPC indexes and the difference with the FPTFPC index for 2015/2017 (in the case of 2015/16 the patterns are similar).

Figure 1. Spatial distribution of the 25 top HCC according to the HMTFPC and FPTFPC methodology.

Source: http://centrossanitarios.sanidadmadrid.org/, Wikipedia and own elaboration.

Figure 2. Dispersion diagrams of productivity index.

Source: Own elaboration.

Table 3 shows the high and significant correlation between the HMTFPC and MALM indexes and the no correlation between these and FPTFPC.

Table 3. Correlations between productivity index.

|	hmtfpc_15_17	fptfpc_15_17	malm15_17
hmtfpc_15_17		0.0673	0.9274
		(262)	(262)
		0.2780	0.0000
fptfpc_15_17	0.0673		0.0356
	(262)		(262)
	0.2780		0.5663
malm15_17	0.9274	0.0356	
	(262)	(262)	
	0.0000	0.5663	

Correlation

(Sample size)

PValue

Source: Own elaboration.

3.1. Comparison of Distributions, Kernel Density Functions and Convergence.

Figure 3 shows the kernel density distributions in the left column and the comparison and dominance analyses in the right column. The results shown through the kernel distributions indicate that productivity of HMTFPC and MALM of the subperiod 2015/17 is shifted ahead of the subperiod 2015/16, denoting convergence. In the case of FPTFPC, no changes occur. Likewise, the 2015/17 productivity distribution dominates the 2015/16 productivity distribution in HMTFPC and MALM as shown in the graphs in the right-hand column of Figure 3. In the case of FPTFPC distributions, there is no dominance.

Figure 3. Kernel distributions and statistical dominance.
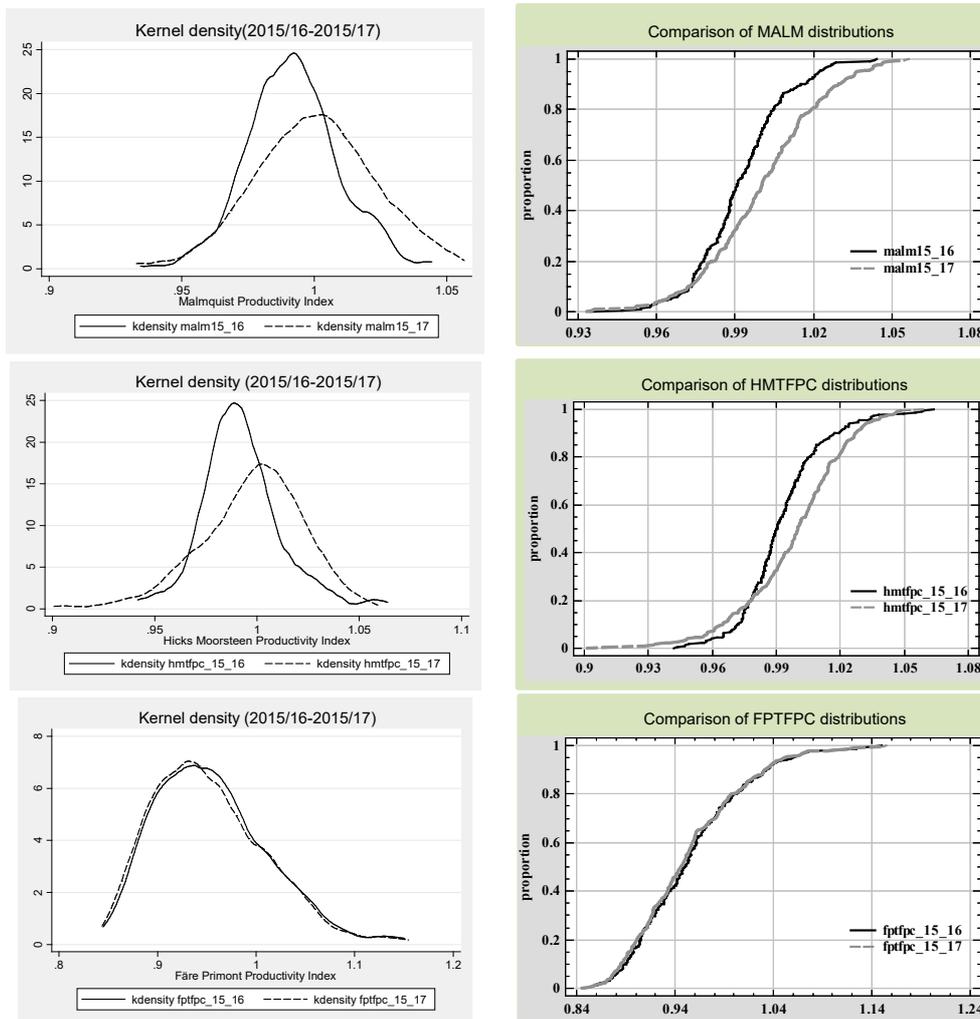
Source: Own elaboration.

Table 4 shows the tests and statistical significance.

Table 4. Kolmogorov-Smirnov statistical dominance test.

2015/16 vs 2015/17	KS test	Pvalue
Malmquist	0.2405	0.0000
Hicks-Moorsteen	0.2328	0.0000
Färe-Primont	0.0458	0.9340

Source: Own elaboration

We begin with β convergence. The idea is to determine if the trend of the HC with lower productivity levels, grow faster than the others, as already commented. The results of Table 5 show that coefficients -0.2638 and -0.2611 are significant at 1% for MALM and HMTFPC respectively, indicating that the least productive HC of each group in the initial subperiod, in general, have obtained productivity growths than most of the HC in that subperiod.

Table 5. Regression analysis of productivity index to the initial 2015/16.

|	cons	β-coefficient bootstrap Std. Err.	Adj R^2
LnMALM	-0.0022	-0.2638**	0.0372
	(0.0016)	(0.0838)	
LnHMTFPC	-0.0045	-0.2611**	0.0409
	(0.0017)	(0.0791)	
LnFPTFPC	-0.0031	0.0988	0.9570
	(0.0009)	(0.0130)	

** significant at the 1% level

CInf: Conventional inference. Inference based on non-corrected var-cov Matrix

BInf: Bootstrapping inference. Inference based on varcov, corrected by Bootstrap method (L = 2000)

Source: Own elaboration.

Finally, Figure 4 shows the convergence made through stochastic kernels according to the contour graphics approach. As can be seen, for the MALM and HMTFPC methodologies the probalistic mass and therefore the intradistributional changes are mostly located above the diagonal, confirming convergence. Whereas with the FPTFPC methodology, the probalistic mass is placed on the diagonal, confirmed stagnation.

Figure 4. Stochastic kernels: contour plot.
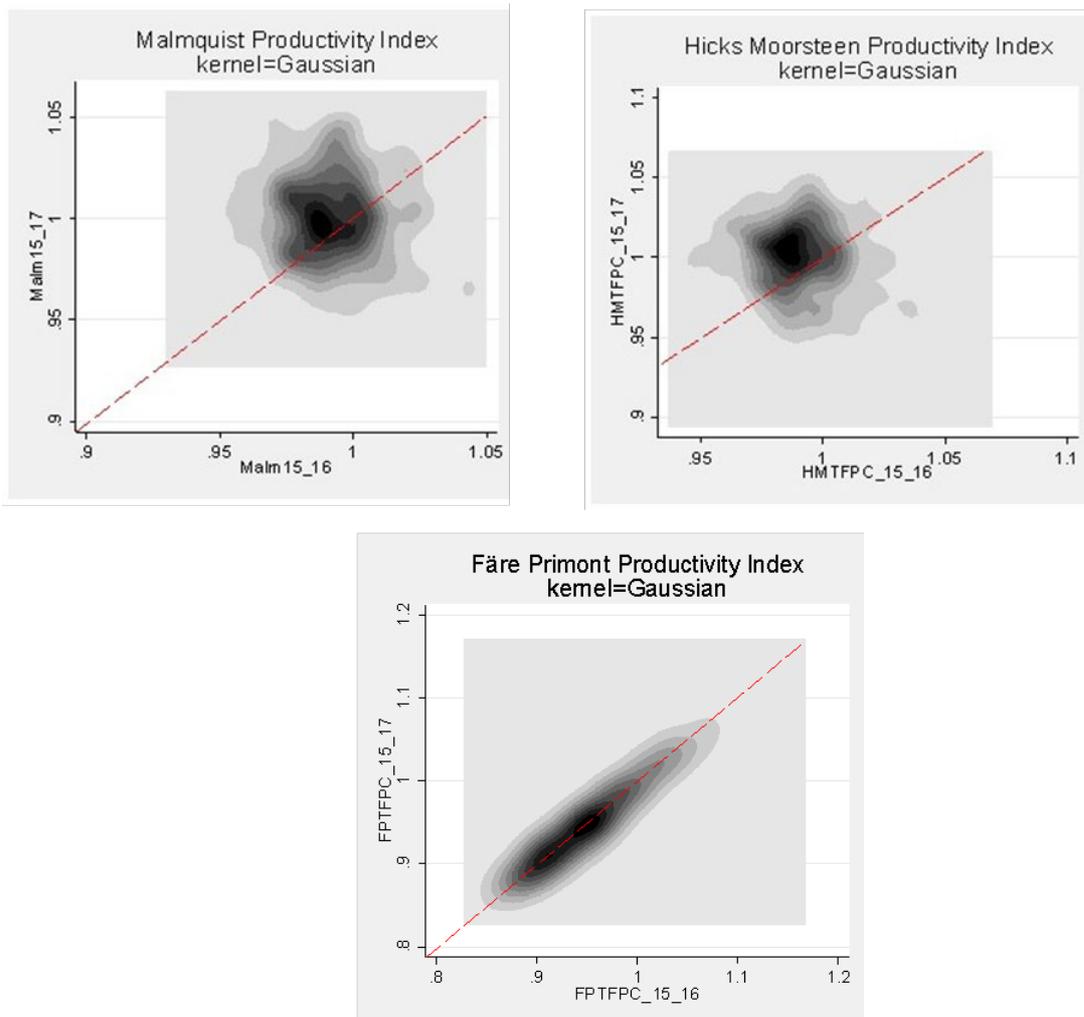
Source: Own elaboration.

4. Conclusions.

A productivity analysis has been carried out from a public database on HC in the Community of Madrid, the capital of Spain. The main objective of this work has focused on extending the existing literature, on the analysis of total factor productivity, with two important contributions: 1) The application and comparison of two robust methodologies, by means of the index, of total factor productivity of Hicks-Moorsteen & Färe Primont which, except for error, have not been previously used in this sector; 2) The regional scope, which has been scarcely analyzed.

The main results reveal decreases in HCC productivity due to the three proposed methodologies. These decreases range between 4.90% and 0.25% for the Färe-Primont & Hicks-Moorsteen index respectively between 2015/17 in average terms. Convergence analysis confirm that this takes place in the case of the Malmquist & Hicks-Moorsteen proposals.

The health budget in Spain is approximately 43% in three regions, where the Community of Madrid is located. The health budget of Madrid in terms of public expenditure per inhabitant is among the three lowest in Spain, in the period of analysis studied. In terms of public policy recommendations and managerial decisions, it should be mentioned that the consequences of the crisis, in terms of higher levels of poverty and unemployment, could require greater efforts at health intervention in the search for higher levels of social efficiency. It seems evident that the maintenance of a world-class position of excellence in the Spanish healthcare system depends on continuing to improve, optimising resources but also providing them.

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