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Efficiency in the generation of social welfare in Mexico: A proposal in the presence of bad outputs ☆

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ABSTRACT

One of the main goals of any country is to secure the general welfare of society, entailing positive levels of education, health and income, coupled with low levels of social inequality. The following paper studies the efficient use of economic and social resources to generate social welfare in the presence of bad outputs in the states of Mexico during 2010. A two-level data envelopment analysis model was used to determine how efficient the 32 states of the Mexican Republic were, considering as model variables the socioeconomic indicators of the three dimensions of human development (education, health and income), and the data on poverty or inequity in the country. The analysis of the results reveals that only 5 of the 32 units studied were efficient in generating welfare and in reducing poverty, while the rest need to increase their welfare levels and especially reduce inequity in education and income using the economic and social resources they possess.

1. Introduction

Social welfare is the satisfaction of basic and secondary needs experienced by individuals in a community [38]. The concept of development should be understood as the process of creating the necessary conditions for increasing opportunities for active participation of a range of actors (civil society, private sector and public sector), in the efficient management of natural, technological and human resources. This process aims to achieve greater autonomy in growth capacity and modify relationships between social groups, thereby leading to economic improvement and a higher level of welfare in the population [88]. Consequently, development seeks to establish a mechanism to solve and attend to problems that concern the welfare of society [116,97].

Three main approaches have been used to measure social welfare: a purely economic approach; an approach based on utility functions; and measurement using social indicators [89]. The approach of social indicators using synthetic indicators to obtain an overall welfare perspective has motivated the creation of various indexes (see, for example, [81]), among which the Human Development Index (HDI) stands out. The HDI was first published in 1990 by the United Nations Development Program (UNDP) and encapsulates the postulates of Amartya Sen [101]. It is a mechanism to measure the level of development of a country, state or region, by determining its level of social welfare, and takes into account the conditions of health, education and personal income (see [59] for its measurement properties). Each of these dimensions is weighted in the same way in the index [116,29,46,82,85,93]. Owing to its simplicity and the ease of access to the statistical information required, it has become the most widely used mechanism for measuring human development, social welfare, and the success or failure of nations' policies [116,68].

The HDI was devised to measure social welfare and human development by considering the different aspects of human life [32].[1] However, since its publication, this index has come under close scrutiny in the literature. Some of the criticisms made concern the theoretical composition of the index: its view of human development is limited since it does not include other variables that affect individuals' welfare such as the environment, participation, social inclusion and equity in any of its three dimensions. Other criticisms are related to technical properties of the HDI, such as how the dimension indexes are derived from raw data; the additive form of aggregation to calculate the indexes by dimension; and equally

[1] Human development is the process by which human choices and their welfare are extended [46]. Basic human development opportunities are: enjoying a long and healthy life; being literate and possessing knowledge; having the necessary resources to achieve a decent standard of living; and participating in community life. If these basic opportunities are lacking many others can also be denied [116,68].

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weighting the three dimensions by aggregating the HDI [106,111,32,33,37,44,49,75,76,80,93].

Despite the criticism, there is a consensus that the HDI goes beyond the simplistic view of GDP *per capita* as a measure of development, capturing several aspects of the human condition [108,30,45]. In this line, Dasgupta and Weale [28] also considered that the HDI sub-indexes provided information on a disaggregated level. There is also a consensus that the concept of human development is very broad and that no index or set of indicators can fully represent it. However, the HDI is a composite index that comes fairly close to the complexity of the concept, taking general aspects of social welfare and including in its last measurements new variables to approach the concept in a better way [108,30,45].

Amartya Sen [101] understands poverty as an absolute phenomenon that is expressed in relative terms, referring to material and economic resources. In this way, poverty directly affects social welfare by influencing the satisfaction of an individual's needs in a society [38]. In addition, poverty is associated with living conditions that make individuals vulnerable; it prevents their basic needs from being met, and precludes their full social integration [114,20,4,62]. The concept of poverty goes beyond the economic dimension, which refers to the people's ability to purchase goods and services with their disposable income. Poverty is also associated with the inability to enjoy various essential aspects, many of which are provided by the State (such as access to education, health or public safety), or that are considered fundamental as economic, social, cultural and human rights. Therefore, the concept of poverty is multidimensional (economic, social, cultural and legal) in nature [113,20,66]. Consequently, from a multidimensional perspective, poverty can be understood as a series of deficiencies in multiple domains or dimensions. The number and type of dimensions to consider are directly related to the concept of what the minimum or acceptable condition is, to ensure a decent standard of living for each and every member of society. In this way, the concept of poverty is directly linked to social welfare, and therefore to human development, since there can be no welfare and development in a society if there is no initiative to combat poverty or inequality of income, education and health [113,118,18,25,4,5,60,64,71,87].

While there are several papers in the literature that discuss and attempt to improve the HDI (for example, [29,75,80–85,111,91,76,37,106–108,44–46,49,96,59,22,10,67,1,65,40,93,48,12,42], among others) only a few studies have evaluated the HDI using Data Envelopment Analysis (DEA). Some of these are [105,110,112,122,125,13,14,16,17,27,32–34,36,47,49,61,69,7,72,73,91,92,94,96]. In particular, few studies have attempted to overcome criticisms of the HDI by establishing equivalent weights for the three dimensions [125,32,33,69], or by addressing the absence of variables that reflect inequity in the dimensions of human development [94].

Research into efficiency in generating the HDI by trying to overcome some of its criticisms is a pending matter in the literature. The aim of this study is to evaluate how efficient the 32 states of Mexico were during 2010 in using their economic and social resources to generate welfare, and at the same time reduce the educational gap, the lack of access to health services and capability poverty. This paper aspires to contribute to the literature by determining an overall index of the efficiency level in the generation of human development through a two-level DEA with DDF. In this way, this efficiency measure incorporates two of the main criticisms of the HDI: arbitrariness in its weights and the absence of variables that reflect inequality in the different dimensions. The inclusion of DDF facilitates the incorporation of the inequity factor to quantify efficiency, thus identifying the maximum simultaneous increase/reduction of the vectors of good and bad outputs [109,23,86]. The advantages of applying a two-level DEA model are first that it allows efficiency to be calculated even with a large number of variables and a relatively small number of observations in the sample, and second it gives freedom to the weights of the dimensions that make up the overall index of efficiency in the generation of human development [63,78].

The rest of the paper is organized as follows. Section 2 describes the methodology used to measure the efficiency in generating social welfare. In Section 3, the selected variables and sources are detailed. The main results are then presented and discussed in Section 4, and finally, the conclusions are given.

2. Methodology

We assume that each Mexican state achieved its performance in each of the HDI dimensions (good outputs) from inputs associated with each factor. We also assume that there are bad outputs to be minimized in each dimension, associated with the level of inequity in each HDI factor [49,91,96]. The objective of the technical efficiency analysis is to quantify the existing potential to minimize the bad outputs, at the same time as maximizing HDI levels, without having to use more inputs than those observed in each Mexican state.

The problem is formulated in a generalized way in order to allow future modifications to the HDI by including more indicators per dimension. Let $j=(1\ldots N)$ be the states for which a level of y_{dj} was observed for the good output in dimension d of the HDI $d=(1\ldots D)$; b_{zk} is the bad output $z=(1\ldots Z)$ obtained in dimension by state k;x_{ij} is the input $i=(1\ldots I)$ used by state k to produce its good and bad HDI outputs. We denote Y as the vector of y_{dj}, B as the vector of b_{zj} and X as the vector of x_{ij}. The technology that defines the HDI generation process is obtained by the set:

$$P(X)=\left\{(Y,B)\middle|\ X\ can\ produce\ (Y,B)\right\} \tag{1}$$

The axioms that $P(X)$ should meet are those usually applied in the theory of production (see, for example, [41]).

The literature has commonly measured the efficiency of any of the analyzed units—known in the literature as decision-making units (DMU), since they are assumed to be free to make their own management decisions—belonging to $P(X)$ by using directional distance functions (DDF), such as the following [109,70,86]:

$$D(X,Y,B)=\max\left(\beta\middle|\ \left(Y+\beta g_y, B-\beta g_b\right)\in P(X)\right) \tag{2}$$

The distance function (2) determines the maximum simultaneous increase/reduction (β) of the vectors of good and bad outputs on the vector's direction $g=\left(g_y,\ g_b\right)$. It is common in the literature to calculate the vector using $g=(Y,\ B)$, as suggested by Chung et al. [23] and Oh [86]. The DEA model generally used to estimate the DDF is (3):

$$\begin{aligned}
&Max=\phi+\varepsilon\left(\sum_{i=1}^{I}s_i^{+}+\sum_{d=1}^{D}s_d^{-}+\sum_{z=1}^{Z}s_z^{+}\right)\\
&s.t.\quad \sum_{j=1}^{N}\lambda_j x_{ij}+s_i^{+}=x_{io} \qquad i=1\ldots I\\
&\sum_{j=1}^{N}\lambda_j y_{dj}-s_d^{-}=(1+\phi)y_{do} \qquad d=1\ldots D\\
&\sum_{j=1}^{N}\lambda_j b_{zj}+s_z^{+}=(1-\phi)b_{zo} \qquad z=1\ldots Z\\
&\sum_{j=1}^{N}\lambda_j=1\\
&\lambda_j, s_d^{-}, s_z^{-}, s_i^{+}\geq 0,\ \phi\ unrestricted\ in\ sign
\end{aligned} \tag{3}$$

where ε is a small non-Archimedean number, ϕ the maximum radial increase/decrease for the good and bad outputs, respectively, s the slack variables and λ_j the intensity vector. Constrain $\sum_{j=1}^{n} \lambda_j = 1$ is incorporated to assume that technology exhibits variable returns to scale (VRS).

In general terms, it has been experimentally shown that if the inequality $3 \times (D+I) \leq N$ (where D is the number of outputs, I the number of inputs, and N the number of DMU analyzed) is not satisfied, the results of DEA models are not acceptable due to the lack of discrimination capability resulting from the low number of efficient DMUs in comparison with the total number of inputs and outputs used [124]. As we will show in Section 3, this inequality is not satisfied in our case. Meng et al. [78] proposed using two-level DEA models when the output and input factors of similar characteristics can be grouped into output and input categories, respectively. By proceeding this way, the discriminatory capability of DEA models with a small number of DMUs is increased [63].

The two-level DEA model proposed in this study for dealing with bad outputs, in its general form, assumes that outputs, bad outputs, and inputs can be grouped into S, B, and M categories respectively. Let A_k be the inputs belonging to the category $k=(1\ldots M)$, B_t the outputs included in category $t=(1\ldots S)$, and C_l the set of bad outputs belonging to the category $l=(1\ldots B)$. The aggregated performance of the kth input category for the j DMU,x_{kj} can be expressed as:

$$x_{kj} = \sum_{f \in A_k} p_f x_{fj}, \sum_{f \in A_k} p_f = 1, \quad p_f \geq 0, \quad f \in A_k, k=1\ldots M \tag{4a}$$

In a similar way, the aggregated performance for the tth output and the lth bad output can be expressed as:

$$y_{tj} = \sum_{g \in B_t} q_g y_{gj}, \quad \sum_{g \in B_t} q_g = 1, \quad q_g \geq 0, \quad g \in B_t, \quad t=1\ldots S \tag{4b}$$

$$b_{lj} = \sum_{h \in C_l} v_h b_{hj}, \sum_{h \in C_l} v_h = 1, \quad v_h \geq 0, \quad h \in C_l, l=1\ldots B \tag{4c}$$

where p_f, q_g and v_h are the weights associated to the f, q, and h category of the inputs, outputs, and bad outputs respectively. By substituting the aggregated factors in (4) in (3) the following program is obtained:

$$\begin{aligned}
&Max = \eta + \varepsilon\left(\sum_{k=1}^{M} \hat{s}_k^{+} + \sum_{t=1}^{S} \hat{s}_t^{-} + \sum_{l=1}^{B} \hat{s}_l^{+}\right) \\
&s.t. \quad \sum_{j=1}^{N} \mu_j \left(\sum_{f \in A_k} p_f \ x_{fj}\right) + \hat{s}_k^{+} = \sum_{f \in A_k} p_f \ x_{fo} \qquad k=1\ldots M \\
&\sum_{j=1}^{N} \mu_j \left(\sum_{g \in B_t} q_g \ y_{gj}\right) - \hat{s}_t^{-} = (1+\eta) \sum_{g \in B_t} q_g \ y_{go} \qquad t=1\ldots S \\
&\sum_{j=1}^{N} \mu_j \left(\sum_{h \in C_l} v_h \ b_{hj}\right) + \hat{s}_l^{+} = (1-\eta) \sum_{h \in C_l} v_h \ b_{ho} \qquad l=1\ldots B \\
&\sum_{j=1}^{N} \mu_j = 1 \\
&\sum_{f \in A_k} p_f = 1 \qquad k=1\ldots M \\
&\sum_{g \in B_t} q_g = 1 \qquad t=1\ldots S \\
&\sum_{h \in C_l} v_h = 1 \qquad l=1\ldots B \\
&\mu_j, \hat{s}_k^{+}, \hat{s}_t^{-}, \hat{s}_l^{+} \geq 0, \quad p_f, q_g, v_h \geq \omega > 0, \quad \eta \quad unrestricted \ in \ sign
\end{aligned} \tag{5}$$

where ω is a small non-Archimedean number to prevent zero weights from being assigned to the second level inputs. This model is nonlinear. In order to be solved using any LP solver, it needs to be linearized. Kao [63] proposed substituting variables for the original DEA model for both its primal and dual forms. Although directional distance functions are considered in this study to deal with bad outputs, an equivalent linearization process for (5) can be applied. By substituting $\alpha_{fj} = p_f \mu_j$, $\beta_{gj} = q_g \ \mu_j$, $\gamma_{hj} = v_h \ \mu_j$, $\varphi_g = q_g(1+\eta)$, and $\delta_h = v_h(1-\eta)$ the following expressions are deduced:

$$\alpha_{fj} = p_f \mu_j \Rightarrow \sum_{j=1}^{N} \mu_j \left(\sum_{f \in A_k} p_f \ x_{fj}\right) = \sum_{j=1}^{N} \sum_{f \in A_k} \alpha_{fj} \ x_{fj} \tag{6a}$$

$$\beta_{gj} = q_g \ \mu_j \Rightarrow \sum_{j=1}^{N} \mu_j \left(\sum_{g \in B_t} q_g \ y_{gj}\right) = \sum_{j=1}^{N} \sum_{g \in B_t} \beta_{gj} \ y_{gj} \tag{6b}$$

$$\gamma_{hj} = v_h \ \mu_j \Rightarrow \sum_{j=1}^{N} \mu_j \left(\sum_{h \in C_l} v_h \ b_{hj}\right) = \sum_{j=1}^{N} \sum_{h \in C_l} \gamma_{hj} \ b_{hj} \tag{6c}$$

$$\varphi_g = q_g(1+\eta) \quad \Rightarrow (1+\eta) \sum_{g \in B_t} q_g \ y_{go} = \sum_{g \in B_t} \varphi_g \ y_{go} \tag{6d}$$

$$\delta_h = v_h(1-\eta) \Rightarrow (1-\eta) \sum_{h \in C_l} v_n \ b_{ho} = \sum_{h \in C_l} \delta_h \ b_{ho} \tag{6e}$$

$$\begin{aligned}
\alpha_{fj} = p_f \mu_j &\Rightarrow \sum_{f \in A_k} \alpha_{fj} = \mu_j \sum_{f \in A_k} p_f \\
&\Rightarrow \sum_{f \in A_k} \alpha_{fj} = \mu_j \quad \forall k \in \{1\ldots M\} \quad \forall j \in \{1\ldots N\}
\end{aligned} \tag{6f}$$

$$\beta_{gj} = q_g \ \mu_j \Rightarrow \sum_{g \in B_t} \beta_{gj} = \mu_j \sum_{g \in B_t} q_g = \mu_j \quad \forall t \in \{1\ldots S\} \quad \forall j \in \{1\ldots N\} \tag{6g}$$

$$\gamma_{hj} = v_h \ \mu_j \Rightarrow \sum_{h \in C_l} \gamma_{hj} = \mu_j \sum_{h \in C_l} v_h = \mu_j \quad \forall l \in \{1\ldots B\} \quad \forall j \in \{1\ldots N\} \tag{6h}$$

$$\varphi_g = q_g(1+\eta) \Rightarrow \sum_{g \in B_t} \varphi_g = (1+\eta) \sum_{g \in B_t} q_g = (1+\eta) \quad \forall t \in \{1\ldots S\} \ \forall j \in \{1\ldots N\} \tag{6i}$$

$$\delta_h = v_h(1-\eta) \Rightarrow \sum_{h \in C_l} \delta_h = (1-\eta) \sum_{h \in C_l} v_h = (1-\eta) \ \forall l \in \{1\ldots B\} \quad \forall j \in \{1\ldots N\} \tag{6j}$$

$$p_f = \frac{\alpha_{fj}}{\mu_j} \geq \omega \Rightarrow \alpha_{fj} \geq \omega \ \mu_j \ \forall f \in A_k \ \forall j \in \{1\ldots N\} \tag{6k}$$

$$q_g = \frac{\beta_{gj}}{\mu_j} \geq \omega \Rightarrow \beta_{gj} \geq \omega \ \mu_j \ \forall g \in B_t \ \forall j \in \{1\ldots N\} \tag{6l}$$

$$v_h = \frac{\gamma_{hj}}{\mu_j} \geq \omega \Rightarrow \gamma_{hj} \geq \omega \ \mu_j \ \forall h \in C_l \ \forall j \in \{1\ldots N\} \tag{6m}$$

$$\frac{\varphi_g}{(1+\eta)} = q_g \geq \omega \Rightarrow \varphi_g \geq \omega(1+\eta) \quad \forall g \in B_t \tag{6n}$$

$$\frac{\delta_h}{(1-\eta)} = v_h \geq \omega \Rightarrow \delta_h \geq \omega(1-\eta) \ \forall h \in C_l \tag{6o}$$

which leads to the following linear program equivalent to (5):

$$\begin{aligned}
&Max \ \eta + \varepsilon\left(\sum_{k=1}^{M} \hat{s}_k^{+} + \sum_{t=1}^{S} \hat{s}_t^{-} + \sum_{l=1}^{B} \hat{s}_l^{+}\right) \\
&s.t. \quad \sum_{j=1}^{N} \sum_{f \in A_k} \alpha_{fj} x_{fj} + \hat{s}_k^{+} = \sum_{f \in A_k} p_f x_{fo} \qquad k=1\ldots M
\end{aligned}$$

$$\sum_{j=1}^{N}\sum_{g\in B_t}\beta_{gj}\ y_{gj}-\hat{s}_t^- = \sum_{g\in B_t}\varphi_g\, y_{go} \qquad t=1\ldots\ S$$
$$\sum_{j=1}^{N}\sum_{h\in C_l}\gamma_{hj}\ b_{hj}+\hat{s}_l^+ = \sum_{h\in C_l}\delta_h\, b_{ho} \qquad l=1\ldots\ B$$
$$\sum_{f\in A_k}\alpha_{fj}=\mu \qquad k=1\ldots\ M,\quad j=1\ldots\ N$$
$$\sum_{g\in B_t}\beta_{gj}=\mu_j \qquad t=1\ldots\ S,\quad j=1\ldots\ N$$
$$\sum_{h\in C_l}\gamma_{hj}=\mu_j \qquad l=1\ldots\ B,\ j=1\ldots N$$
$$\sum_{g\in B_t}\varphi_g=(1+\eta) \qquad t=1\ldots\ S$$
$$\sum_{h\in C_l}\delta=(1-\eta) \qquad l=1\ldots\ B$$
$$\alpha_{fj}\ge\omega\ \mu_j \qquad \forall f\in A_k, k=1\ldots\ M, j=1\ldots\ N$$
$$\beta_{gj}\ge\omega\ \mu_j \qquad \forall g\in B_t, t=1\ldots\ S, j=1\ldots\ N$$
$$\gamma_{hj}\ge\omega\ \mu_j \qquad \forall h\in C_l,\ l=1\ldots\ B, j=1\ldots\ N$$
$$\varphi_g\ge\omega\ (1+\eta) \qquad \forall g\in\ B_t$$
$$\delta_h\ge\omega(1-\eta) \qquad \forall h\in\ C_l$$
$$\sum_{j=1}^{N}\mu_j=1$$
$$\mu_j,\hat{s}_k^+,\hat{s}_t^-,\hat{s}_l^+,\quad \alpha_{fj},\beta_{gj},\gamma_{hj},\varphi_g,\delta_h\ge0, p_f\ge\omega,\eta\ \text{unrestricted in sign} \tag{7}$$

The weights allocated by the two-level DEA model at the second level could be zero, since the only restriction is that the sum of the weights belonging to the same category must be equal to one. Consequently, the model may assign a weight of one to one input or output and zero to the rest, which could be considered as a problem in some real applications. In order to avoid this problem restrictions are usually imposed on weights. However, this makes sense in the case of having some kind of empirical evidence to determine the accepted variation ranges for the weights. For instance, Meng et al. [78] allowed a variation of 20% with respect to the relative importance for some research outputs of 15 Chinese research institutes obtained after an analytic hierarchy process (AHP). In our case, there are no clues on how the weight restrictions should be set; consequently we opted simply to avoid zero weights by establishing that the minimum weights must be at least equal to a small value ω[2]. Our intention in proceeding thus is to adapt the model to the available data in the best and most realistic way possible. However, assurance region (AR) restrictions [6,95] could be considered for the second level weights both in (5) and then also linearized to be included in (7) by substituting variables as previously described if data are available.[3]

3. Data and variables

To apply the methodology described above, to evaluate the efficiency in generating social welfare, the good and bad outputs and the inputs had to be defined for each HDI dimension (education, income and health).

The indicators usually used to calculate the HDI were taken as good outputs; that is, GDP *per capita*, literacy, and life expectancy at birth. Proxy variables for the inequity in each dimension were considered as the bad outputs. The variables chosen were education gap for the education dimension, lack of access to health services for the health dimension, and capability poverty for the income dimension. In the Mexican case, the *Consejo Nacional de Evaluación de la Política de Desarrollo Social* (National Council for the Evaluation of Social Development Policy) [25] considers these variables as the best to represent the existence of poverty and inequality in the country, following a theoretical discussion about the multivariate concept of poverty, which took shape in the General Law for Social Development in Mexico [35]. The variable of education gap reflexes the people between 3 and 15 years who do not have basic education and not attend to a formal education center; the lack of access to health services variable denote people who have no affiliation or right to receive medical services from any institution; and the capability poverty implies the number of people whose income does not allow them access to a basic basket of goods and services [113,118,18,25,4,5,60,64,71,87].

The study period of this research is 2010, however, to collect in a better way the longitudinal impact of the inputs on the outputs, we took the average value of 20 years (1990–2010) for each inputs.[4] The information on these variables was obtained from the statistical databases of the *Instituto Nacional de Estadística y Geografía* (Mexican National Institute of Statistics, Geography and Informatics) [50–58], the *Secretaría de Educación Pública* (Secretary of Public Education) [102,103], the *Secretaría de Salud* (Secretary of Health) (2013a-b), the *Consejo Nacional de Población y Vivienda* (National Population and Housing Council) [24], the *Banco de México* (Bank of Mexico) [11], the *Secretaría de Hacienda y Crédito Público* (Ministry of Finance and Public Credit) [104], the *Consejo Nacional de Evaluación de la Política de Desarrollo Social* (National Council for the Evaluation of Social Development Policy) [26] and the UNDP Human Development Reports for Mexico [113,117].

The selection of inputs for each dimension was based, first, on the theory underlying the behavior of the components of the HDI dimensions of income, education and health dimensions. To this end, according to the theories of Veenhoven [119], UNDP [115,116,117], Marshall and Shortle [74], Seijas [100], Despotis [31,32,33], Ramos and Silber [92], Arcelus et al. [7], Bollou et al. [16]; Afonso and Fernández [2], Lozano and Gutierrez [69], Emrouznejad et al. [39], Viloria et al. [120], Blancas and Domínguez [15], Zhou et al. [125], Bougnol et al. [17], Despotis et al. [34], Hatefi and Torabi [47] Shetty and Pakkala [105], Mojica et al. [79], Blancard and Hoarau [13],Cravioto et al. [27], Domínguez-Serrano and Blancas [36], González et al. [43], Ülengin et al. [112], Jahanshahloo et al. [61], Yago et al. [123], Mahani et al. [72], Tofallis [110], Blancard and Hoarau [14], Reig-Martínez [94], and Wu et al. [122], it is possible to identify the inputs that affect the performance of each of the dimensions of human development, which are:

- *Education:* Public spending on education, children that reach the fifth grade, female/male literacy ratio, female/male enrolment ratio, GDP *per capita*, total number of teachers, and available classrooms and schools.
- *Health:* Population using improved sanitation facilities, population using improved drinking-water sources, population with access to medicines, immunized children of one year old, births attended by skilled health personnel, number of physicians, health expenditure, malnourished people, people with HIV/AIDS, insured population, cigarette consumption, infant mortality rate, under-five mortality rate, maternal mortality rate, GDP *per capita*, and hospital beds.

[2] For computational purposes, we will assume that $\omega=0.01$.
[3] Equations associated to AR restrictions are not developed since they are not necessary for the case here analyzed.

[4] It is noteworthy that the average values and the values of the inputs 2010, no present major changes in their behavior and distribution. So it is expected that the results of efficiency do not change greatly.

- *Income:* Average annual change in the consumer price index, inequality index, exports, imports, direct foreign investment, total debt service, development assistance, public expenditure, *per capita* electricity consumption, proportion of population that uses the Internet, mean years of schooling (of adults), economically active population, employed persons, number of businesses, gross capital formation, wages and salaries.

Factor analysis was performed to extract the principal components, in order to reduce the number of inputs. The Kaiser-Meyer-Olkin (KMO) measure obtained was greater than 0.60, and Bartlett's test of sphericity was high, with a slight level of significance, thus confirming the validity of their application. The final inputs selected, using the criterion of Principal Component Analysis (PCA), were as follows: for the education dimension with a variance explained of 92.07%, the total number of teachers and available classrooms; for the health dimension with a variance explained of 92.95%, the number of physicians and insured population; and for the income dimension with a variance explained of 90.15%, public expenditure, mean years of schooling (of adults) and employed persons. Added to this were carried out econometric tests, for each dimension of the human development (education, health and income), with panel data, least squares and fixed effects, thus corroborating the direct impact of the inputs on the outputs. This implies that in the three dimensions of the HDI, the chosen inputs affect the levels of literacy, life expectancy at birth and GDP *per capita*. Similarly, the econometric results show that the outputs are not correlated between them, and that the output of one dimension are not highly correlated with the inputs from another dimension (Table 1).

Finally, the total number of inputs, outputs, and bad outputs selected was 13 and the total number of states was 32. The model (3) was calculated with all these variables and did not provide discriminatory results, as expected. In fact, just three states were considered inefficient in generating HDI. For this reason, the two-level model described in Section 3 was proposed for this case. In order to apply the model, the inputs were grouped into three categories while the good and bad outputs remained as independent variables. Consequently, the first category is made up of the education dimension inputs: number of teachers and available classrooms. The second category is formed by the income dimension inputs: public expenditure, level of schooling and working population. Finally, number of physicians and insured population comprise the third category related to the health dimension. All the variables were normalized in order to remove scale differences in the weighted sums of model (5) for each input category. The normalization criterion was $\bar{x}_{ij} = \frac{x_{ij}}{\max_i (x_{ij})} \times 100$ as suggested by Meng et al. [78].

4. Results

Table 2 shows the results of the analysis of efficiency in generating social welfare. Model (7) was estimated under three assumptions for the directional vector to consider different possible priorities when projecting inefficient units onto the frontier. The first column (GO and BO oriented) shows the value for η assuming that both good and bad outputs improve simultaneously. In this case the directional vector used was $g=(Y,\ B)$ to determine the maximum increase/decrease achievable simultaneously for both good and bad outputs. The results, when we assume that the priority is to improve the good outputs while maintaining the level of bad outputs, are shown in the second column of the table (GO oriented). In this case, the directional vector used was $g=(Y,\ 0)$ as in Watanabe and Tanaka [121]. The last column (BO oriented) shows the estimation for η assuming that the priority is to reduce the bad outputs while maintaining the observed levels for the good outputs, thus $g=(0,\ B)$.

When the priority is to improve both good and bad outputs, there is just a 1.343% average potential improvement in the generation of HDI; in other words, the good/bad output could be increased/decreased by this percentage while using the same or fewer inputs than those observed. This small potential improvement is due mainly to the fact that one of the good outputs is life expectancy at birth with a small range of variation among the states, approximately 3.60%. Consequently, the radial expansion/reduction of the good/bad outputs can be this percentage at most. For this reason, if the approach were to improve just the good outputs as considered originally by the PNUD, the potential improvement would be similar (1.454%). However, when the aim is to reduce the inequalities, the results show a larger potential of average improvement (27.202%), proving that the reduction of inequity should be one of the country's main priorities. This result also reinforces the importance of including inequity measures for each dimension when calculating the HDI as proposed in this paper.

Five states appear as efficient in generating HDI under the three evaluations: Aguascalientes, Baja California Sur, Campeche, México and Nuevo León. Distrito Federal and Colima also present high efficiency levels. The reason why these entities appear in the model as the most efficient is because regionally they are characterized by a high level of sectorial development (agricultural, industrial or service), which stimulates economic growth and makes them stand out in social welfare. This situation is reflected in the behavior of indicators such as GDP *per capita*, literacy, life expectancy at birth, education gap, lack of access to health services, capability poverty, among other socioeconomic indicators [25,24,11,50–58,98,99,104,115,117].

Table 1
Inputs and outputs descriptive statistics.
Source: Own calculations.

Variable	Measurement unit	Type	Average	Standard Deviation	Maximum	Minimum
Public expenditure	Millions of Mexican Pesos	Input	17,289	13,890	63,601	3789
Mean years of schooling (of adults)	Years	Input	7.50	0.93	9.74	5.49
Employed persons	Persons	Input	1,086,655	976,055	4,596,126	179,715
GDP *per capita*	Mexican Pesos	Output	12,387	6346	34,200	4557
Capability poverty	Persons	Bad output	955,890	901,977	3,990,475	81,237
Number of physicians	Persons	Input	1681	1752	9575	390
Insured population	Persons	Input	1,484,486	1,403,937	6,271,291	311,303
Life expectancy at birth	Years	Output	75.48	0.65	76.50	73.84
Lack of access to health	Persons	Bad output	1,165,334	1,232,175	5,960,934	107,535
Total number of teachers	Persons	Input	37,855	32,503	140,478	5913
Available classrooms	Classrooms	Input	25,779	18,217	67,997	4166
Literacy	Persons	Output	2,263,284	1,998,822	10,101,748	431,553
Education gap	Persons	Bad output	680,000	566,338	2,226,288	87,705

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Table 2
Efficiency scores for the HDI generation.
Source: Own calculations.

State	GO and BO oriented	GO oriented	BO oriented
Aguascalientes	0.000%	0.000%	0.000%
Baja California	0.237%	0.328%	6.251%
Baja California Sur	0.000%	0.000%	0.000%
Campeche	0.000%	0.000%	0.000%
Chiapas	1.773%	2.671%	10.282%
Chihuahua	1.268%	1.343%	18.766%
Coahuila	2.734%	3.187%	70.285%
Colima	0.062%	0.058%	2.242%
Distrito Federal	0.021%	0.124%	1.454%
Durango	3.796%	4.892%	36.659%
Guanajuato	0.613%	0.738%	31.622%
Guerrero	2.956%	1.939%	62.284%
Hidalgo	2.430%	2.589%	46.295%
Jalisco	0.946%	0.602%	24.735%
México	0.000%	0.000%	0.000%
Michoacán	2.317%	2.317%	68.173%
Morelos	0.639%	0.682%	36.892%
Nayarit	1.830%	1.890%	23.987%
Nuevo León	0.000%	0.000%	0.000%
Oaxaca	3.559%	2.699%	67.431%
Puebla	2.147%	2.147%	61.861%
Querétaro	0.926%	0.926%	28.768%
Quintana Roo	0.784%	0.961%	17.904%
San Luis Potosí	1.689%	1.949%	26.361%
Sinaloa	2.988%	3.296%	23.928%
Sonora	1.751%	1.805%	18.568%
Tabasco	1.567%	1.793%	27.872%
Tamaulipas	0.622%	1.893%	32.539%
Tlaxcala	0.472%	0.473%	28.782%
Veracruz	2.876%	2.876%	39.945%
Yucatán	1.559%	1.674%	21.276%
Zacatecas	0.422%	0.678%	35.287%
Descriptives			
Mean	1.343%	1.454%	27.202%
Standard deviation	0.012	0.012	0.216
Maximum	3.796%	4.892%	70.285%

Table 3
Additional potential reduction for the bad outputs.
Source: Own calculations.

State	Education gap	Capability poverty	Lack of Access to health
Aguascalientes	0.000%	0.000%	0.000%
Baja California	12.550%	0.000%	2.345%
Baja California Sur	0.000%	0.000%	0.000%
Campeche	0.000%	0.000%	0.000%
Chiapas	7.890%	0.000%	0.000%
Chihuahua	0.000%	12.768%	17.645%
Coahuila	79.839%	36.533%	76.672%
Colima	28.352%	0.000%	21.969%
Distrito Federal	4.672%	0.000%	0.000%
Durango	14.195%	0.000%	0.000%
Guanajuato	53.138%	0.000%	57.162%
Guerrero	73.339%	33.098%	65.912%
Hidalgo	36.134%	3.964%	41.823%
Jalisco	43.330%	4.959%	18.528%
México	0.000%	0.000%	0.000%
Michoacán	62.668%	30.249%	55.994%
Morelos	29.661%	16.708%	0.000%
Nayarit	27.876%	0.000%	39.040%
Nuevo León	0.000%	0.000%	0.000%
Oaxaca	62.564%	44.955%	64.387%
Puebla	51.672%	40.680%	59.750%
Querétaro	31.552%	1.567%	0.000%
Quintana Roo	0.000%	0.000%	0.000%
San Luis Potosí	37.095%	0.000%	22.826%
Sinaloa	17.843%	0.000%	0.000%
Sonora	5.785%	0.000%	9.495%
Tabasco	11.377%	0.000%	27.028%
Tamaulipas	1.452%	8.329%	2.340%
Tlaxcala	0.000%	39.917%	11.702%
Veracruz	64.242%	32.704%	72.681%
Yucatán	39.281%	0.000%	41.145%
Zacatecas	38.472%	0.000%	8.937%
Descriptives			
Mean	26.093%	9.576%	22.418%
Standard deviation	0.250	0.153	0.262
Maximum	79.839%	44.955%	76.672%

The least efficient states in generating HDI are Coahuila, Hidalgo, Michoacán, Oaxaca, Veracruz, Durango, Guerrero and Sinaloa. Efficiency results in the case of these entities are explained by the wide economic gap in which the bulk of their populations live, as well as by the social instability that is manifested through marginalization, poverty and insecurity. The socioeconomic instability of these states is evidenced by the low levels of human development, literacy, and life expectancy at birth, together with education gap, lack of access to health services, and capability poverty [24,25,102–104,50–58,115,117].

The results for efficiency revealed by the DEA model highlight the existence of a socioeconomic gap in Mexico. However, this regional disparity has been present since its formation. The development model implemented in Mexico—Import Substitution Industrialization (1940–1980) and Neoliberalism (1982 to the present)—has increased the inequality among the Mexican states, allowing social and economic well-being to be concentrated in just a few states, and leaving many of the rest in a position of vulnerability [3,8,9,90]. Thus it is not a surprise that Aguascalientes, Baja California Sur, Campeche, México, Nuevo León, Distrito Federal and Colima are the most efficient states because these entities have traditionally benefited most from national development policies, and this is manifested in different socioeconomic indicators. On the other hand, the states of Coahuila, Hidalgo, Michoacán, Oaxaca, Veracruz, Durango, Guerrero and Sinaloa are the entities that have not usually enjoyed the same support for development, and that obtained the highest levels of inefficiency in generating human development and reducing poverty and inequality in the DEA model.

Since the greatest potential improvements have been identified when the priority is to reduce the bad outputs, it seems interesting to analyze the additional improvement of the radial reduction in the bad outputs for each HDI dimension. This information is depicted in Table 3 expressed as a percentage of the original observed values. The education and health dimensions are those that require most improvement, both with more than 22% of additional potential reduction. There is therefore a need to implement public policies focused on redistribution of social welfare in education and health; otherwise a large proportion of the population will not benefit, so the impact in terms of human development and welfare will be less effective than it should be. The smaller additional improvement of the radial reduction is for the capability poverty dimension, around 9.5%. Coahuila, Guerrero, Michoacán, Oaxaca, Puebla and Veracruz are the states with a great additional potential for improvement in the three HDI dimensions.

By analyzing the relative weights of the inputs in each dimensions of human development (see Table 4), we could distinguish nationwide that in the education factor the input classrooms is the best managed, with an average total weight of 0.671. As for the income dimension, the inputs more efficiently used, reflected in the average total weight, were the number of employed persons (0.454) and mean years of schooling (0.326). Finally, in the health dimension, the variable more efficiently used was insured population, with an average total weight of 0.678. It is important to highlight that the efficient use of the resources in this case is associated with the government efforts to increase social

Table 4
Weights of the inputs in each dimensions of human development.
Source: Own calculations.

State	Category 1: Education		Category 2: Income			Category 3: Health	
	Teachers	Classrooms	Public expenditure	Mean years of schooling (of adults)	Employed persons	Physicians	Insured population
Aguascalientes	0.910	0.090	0.144	0.268	0.588	0.064	0.936
Baja California	0.915	0.085	0.128	0.102	0.770	0.752	0.248
Baja California Sur	0.314	0.686	0.096	0.497	0.408	0.045	0.955
Campeche	0.317	0.683	0.202	0.134	0.663	0.339	0.661
Chiapas	0.218	0.782	0.899	0.046	0.056	0.063	0.937
Chihuahua	0.097	0.903	0.123	0.086	0.791	0.896	0.104
Coahuila	0.089	0.911	0.739	0.180	0.081	0.085	0.915
Colima	0.192	0.808	0.098	0.789	0.113	0.175	0.825
Distrito Federal	0.588	0.412	0.121	0.475	0.404	0.155	0.846
Durango	0.073	0.927	0.098	0.080	0.822	0.283	0.717
Guanajuato	0.023	0.977	0.057	0.868	0.075	0.132	0.868
Guerrero	0.281	0.719	0.135	0.112	0.753	0.152	0.848
Hidalgo	0.489	0.511	0.134	0.070	0.796	0.896	0.104
Jalisco	0.241	0.759	0.329	0.215	0.455	0.599	0.401
México	0.157	0.843	0.333	0.393	0.274	0.091	0.909
Michoacán	0.277	0.723	0.208	0.279	0.514	0.125	0.875
Morelos	0.291	0.709	0.083	0.139	0.778	0.287	0.713
Nayarit	0.811	0.189	0.189	0.403	0.408	0.271	0.729
Nuevo León	0.249	0.751	0.076	0.248	0.676	0.079	0.921
Oaxaca	0.188	0.812	0.210	0.170	0.620	0.177	0.823
Puebla	0.797	0.203	0.168	0.395	0.437	0.492	0.508
Querétaro	0.070	0.930	0.155	0.434	0.411	0.842	0.158
Quintana Roo	0.129	0.871	0.073	0.830	0.097	0.097	0.903
San Luis Potosí	0.705	0.295	0.244	0.427	0.329	0.451	0.549
Sinaloa	0.010	0.990	0.096	0.835	0.070	0.252	0.748
Sonora	0.189	0.811	0.051	0.186	0.763	0.621	0.379
Tabasco	0.245	0.755	0.128	0.644	0.228	0.331	0.669
Tamaulipas	0.101	0.899	0.119	0.085	0.797	0.135	0.865
Tlaxcala	0.930	0.070	0.177	0.573	0.250	0.207	0.793
Veracruz	0.238	0.762	0.872	0.077	0.051	0.166	0.834
Yucatán	0.082	0.918	0.192	0.278	0.530	0.493	0.507
Zacatecas	0.298	0.702	0.362	0.120	0.518	0.569	0.431
Descriptives							
Average	0.329	0.671	0.220	0.326	0.454	0.322	0.678
Std. Dev.	0.281	0.281	0.217	0.251	0.265	0.261	0.261
Maximum	0.930	0.990	0.899	0.868	0.822	0.896	0.955
Minimum	0.010	0.070	0.051	0.046	0.051	0.045	0.104

welfare, however, it still required overcome the problems of inequality in national and state level (Table 5).

At state level the DMUs considered to be efficient (Aguascalientes, Baja California Sur, Campeche, México and Nuevo León) behave differently with respect to the weights of the inputs in each of the human development dimensions. In education, Aguascalientes was more efficient in its use of teachers, while Baja California Sur, Campeche, México and Nuevo León were more efficient in their use of classrooms. This difference in behavior is due to the endowment and characteristics of inputs in these states [102,103,50–58,25]. It is very important to note that in most of the states the input teachers is the most inefficient variable and is forcing the efficient use of infrastructure. This behavior can be explained by the lack of training and refresher courses for teachers, as well as by the number of days devoted to teaching, which is influenced by strong union activity.

Regarding the income dimension, and considering the efficient DMUs, the state of México was more efficient in its use of the input variable level of mean years of schooling; Aguascalientes and Nuevo León were more efficient in their use of the input employed persons; and Baja California used both inputs efficiently. This circumstance is due to the allocation of resources, and to the type of economic activity that the states prioritize [11,24,25,50–58,104]. The inefficiency detected in the public spending input in all states of the Mexican republic can be explained by the excess of non-productive activities in the government apparatus, which, far from promoting social welfare, negatively impact on the development of activities that enhance economic well-being.

Finally, in the health dimension, considering the efficient DMUs (which in this case are the DMUs with a higher provision of inputs), all DMUs used the insured population input more efficiently. This may be due to the health institutions' obligation to respond effectively and efficiently—using the inputs they have—to citizens that need the service, and it will usually be the insured population who demands the service [24,25,50–58,98,99]. This finding shows that health sector employees may not be inefficient, but rather that only a small percentage of the population has access to the health system. It is therefore essential to establish mechanisms to reduce the inequality in access to the health system.

An additional estimation was carried out without optimizing the variable life expectation at birth since it has been shown that its small differences among states reduces the discriminatory capability of the model (see Table 5). From a modeling point of view, the term $(1+\eta)$ was removed from the restriction associated to this variable. The global improvement rose to almost 17% in this case. This fact highlights the existence of an important margin to increase the outputs of income and education dimensions as well as to reduce the inequity in the three dimensions. When the model approach is to maximize the good outputs, the potential improvement is considerably greater (about 38%). Consequently, measures should be taken to assure that all the states achieve the best HDI levels according to their available resources. The results

Table 5
Efficiency scores for the HDI generation (without life expectancy at birth optimization).*Source*: Own calculations.

State	GO and BO oriented	GO oriented	BO oriented
Aguascalientes	0.000%	0.000%	0.000%
Baja California	2.819%	7.153%	6.251%
Baja California Sur	0.000%	0.000%	0.000%
Campeche	0.000%	0.000%	0.000%
Chiapas	24.698%	19.717%	10.282%
Chihuahua	8.563%	19.679%	18.766%
Coahuila	51.037%	103.457%	70.285%
Colima	0.759%	0.650%	2.242%
Distrito Federal	9.678%	19.562%	1.454%
Durango	18.933%	56.419%	36.659%
Guanajuato	14.172%	24.598%	31.622%
Guerrero	41.195%	126.686%	62.284%
Hidalgo	31.552%	105.262%	46.295%
Jalisco	9.270%	25.228%	24.735%
México	0.000%	0.000%	0.000%
Michoacán	37.702%	85.532%	68.173%
Morelos	17.004%	54.170%	36.892%
Nayarit	10.698%	31.575%	23.987%
Nuevo León	0.000%	0.000%	0.000%
Oaxaca	39.252%	118.305%	67.431%
Puebla	41.632%	62.750%	61.861%
Querétaro	21.897%	33.762%	28.768%
Quintana Roo	12.678%	25.651%	17.904%
San Luis Potosí	17.789%	35.203%	26.361%
Sinaloa	9.715%	22.082%	23.928%
Sonora	12.050%	24.136%	18.568%
Tabasco	14.128%	36.778%	27.872%
Tamaulipas	11.452%	21.673%	32.539%
Tlaxcala	17.278%	44.231%	28.782%
Veracruz	17.327%	41.502%	39.945%
Yucatán	12.457%	32.796%	21.276%
Zacatecas	18.881%	52.037%	35.287%
Descriptives			
Mean	16.394%	38.456%	27.202%
Standard deviation	0.138	0.353	0.216
Maximum	51.037%	126.686%	70.285%

obtained when the model is oriented to reduce the bad outputs are, obviously, the same as in Table 2 since the output variables are not optimized. The same overall efficient states appear in this estimation.

Coahuila, Guerrero, Michoacán, Oaxaca and Puebla have very low efficiency coefficients, above 37%. The fact that Guerrero and Oaxaca appear again as the worst performers confirms that they are the states with the lowest levels of welfare in education, health and income, as well as having the highest number of people living in poverty. These results are in line with the dynamics of the national economy, since they are usually the most backward and thus the most socioeconomically vulnerable in terms of violence, marginalization, poverty and insecurity.

5. Conclusions

Social welfare is the satisfaction of a society's basic and secondary needs, and is one of the main goals of any country. The quest to determine the level of social welfare has resulted in several consolidated composite indexes, the most representative of which is the HDI. The HDI uses three dimensions (education, health and income) to characterize the level of welfare in a society. However, this index has come under close scrutiny in the literature. This study revisited the representativeness of the HDI and considered some of the main criticisms (the arbitrariness in establishing weights by dimension of human development, and the inclusion of variables of inequity for HDI dimensions) in an attempt to assess how efficiently economic and social resources were used to generate social welfare and reduce inequality indicators in the 32 states of the Mexican Republic in 2010.

The results of this study reveal that Mexico and its states are more efficient at managing the use of their existing inputs to produce HDI than at reducing its inequity. These results reflect poor national initiatives to combat marginalization and inequality of income, health and education. At the state level, Aguascalientes, Baja California Sur, Campeche, México and Nuevo León emerge as the most efficient in generating welfare in the three HDI dimensions and in reducing inequality, owing to their notable performance in economic and social issues. They had high indicators of GDP *per capita*, literacy and life expectancy at birth, and low capability poverty, education gap, and lack of access to health services, compared to the other states of the Republic. The poorest performers in efficiently managing their resources to produce HDI and reduce inequity are Coahuila, Hidalgo, Michoacán, Oaxaca, Veracruz, Durango, Guerrero and Sinaloa. Greater potential improvements were identified for the inequity variables, which reinforce the importance of considering them when constructing or analyzing any composite index of HDI as in this study.

The main limitation of this work is that it does not consider environmental factors as bad outputs but, unfortunately, there is no reliable information on this at state level in Mexico. Finally, future research could take a dynamic analysis approach, explore which institutional and spatial factors affect efficiency in generating welfare, develop a dual model to calculate the weight of each category or treat the complex relationship between inputs and outputs with a network DEA model.

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