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Construction of a Digital Divide Index for the Study of Latin American Countries

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Abstract

The digital divide is the inequality between individuals of a country in relation to Internet access and the use of information and communications technology. This article aims to analyse the digital divide in a number of Latin American countries to diagnose the weaknesses of the region and to identify the elements requiring improvement. Through the joint use of fuzzy subsets and distances, an index is proposed to measure the digital divide, which allows the ordering of the countries studied, from a set of variables related to the digital divide taken from the literature. The results confirm the dispersion of the digital divide in Latin America. The paper encourages governments in the region to look at their strategic policies to reduce the distance to the ideal level.

Keywords

Digital divide, fuzzy subsets, distances, Latin American, index

1. Introduction

For the first time in human history, since economic leaders have had to overcome multiple sources of friction to become the dominant economic force today, the development of trade is the story facilitating interaction and reducing costs (Zwillenberg, Field, & Dean, 2014); however, in this process not all regions develop in the same way, generating inequality, and different levels of economic development have a number of consequences for the global imbalance (Alex, Rodrigo, & Garabet, 2016). One of these gaps, the digital divide, is related to the disparities between regions and countries in the use of new technologies of communication and the Internet (TICs) and the differences in opportunities for the adoption of information and communication technologies presented by countries worldwide (Chang, Kim, Wong, & Park, 2015). In the most advanced countries, the common use of the Internet depends on individual preferences, interests or generational limits, while, in countries with low socioeconomic levels, it is the digital divide that determines access to these technologies (Landau, 2012). The current acceleration of technological change and the slowdown of the regional economy presents a scenario called the second economy (digital), in which the full revolutions in consumption and production are becoming different (Katz, Agudelo, Bello, & Rojas, 2015).

Measurements of the digital divide are not unified. International organizations, such as the Organisation for Economic Co-operation and Development (OECD) or the International Telecommunication Union (ITU), take into account indicators of Internet use by the population under the effect moderator of socioeconomic levels, basically income and educational level (Peral-Peral, Arenas-Gaitán, & Villarejo-Ramos, 2015). However, the digital divide is a broader concept, which not only measures access to knowledge on the use of technology but also gives priority to measuring more fully the differences in access to and use of the Internet, having physical, economic, and social aspects (Jordán, Galperin, & Peres, 2010).

The last report by the Economic Commission for Latin America and the Caribbean (CEPAL) on information technology and the Internet by 2015 in Latin America indicated alarm about the disparity between regions regarding the adoption of the Internet. In the area Nicaragua has the lowest number of Internet users per capita and Chile the largest, with a gap between these two countries that increased from 31% in 2006 to 55% in 2013 (Katz et al., 2015). Other countries in the area, such as Paraguay, El Salvador, Honduras, and Guatemala, despite having high growth rates, remain at the bottom of the distribution, showing a large distance from the best-positioned countries, which are Chile, Argentina, and Uruguay. Only Ecuador, Colombia, the Bolivarian Republic of Venezuela, and the Plurinational State of Bolivia are maintained in media terms, but the growth of the whole area is poor, with five countries in which the population using the Internet does not exceed 30%, eight countries in which it does not exceed 50%, and only six countries in which the figure is greater than 50% (NU. CEPAL, 2015).

Other relevant information about Internet access in the area concerns access to the Internet via a fixed connection. In all of the above countries in 2014, the gap between access in urban areas and access in rural areas exceeded 10% on average; it was the largest in Brazil, Colombia, and Panama with over 30% followed by Chile, Costa Rica, Ecuador, Paraguay, Peru, and Uruguay with 20%. Highlighting another disturbing fact regarding the gap between countries in the area, the percentage of rural households with Internet access in Costa Rica and Uruguay is greater than the percentage of urban households with access in the Plurinational State of Bolivia, Guatemala, and Salvador.

Meanwhile, inequality in Internet access shows Ginni coefficient difference values between 0.1 and 0.5 (total households with Internet/total households), the lowest being in Uruguay with only 0.13 points and the highest being in Colombia with 0.46. A driving factor of Internet use in the region is the high growth rate of mobile broadband, because of its diversity and affordability with the use of mobile telephony, which introduced in 2013 an average of 30% penetration in Latin America, with annual growth of 22% compared with 5% for fixed broadband. The gap between countries in the area is small, and the largest difference, between Uruguay (highest penetration) and Honduras (lowest penetration), is 20.2% (NU. CEPAL, 2015). In terms of unequal access to the Internet due to the socioeconomic level, it is apparent that within each country the number of households with Internet access in the richest quintile of the population (quintile V) is greater than 5 to the equivalent number of households in the poorest quintile (quintile I) in countries like Argentina, Brazil, Colombia, Uruguay, and the Bolivarian Republic of Venezuela. As worrisome cases, this figure is 14 times worse in Ecuador or Bolivia and more than 50 times worse in Paraguay and Peru (Katz et al., 2015). To end this scenario, it is emphasized that in recent years Latin American governments have encouraged informal access to ICT services and the Internet, focusing on policies for broadband infrastructure, market liberalization and changes in the regulation of the sector with the objective of promoting a reduction in the digital divide.

This paper aims to propose an index to measure the international digital divide in aggregate, offering a model of international indicators that can provide an overview of the distances between Latin American countries and the distances between these and the rest of the world. More specifically, it is intended, firstly, from the aggregate indicators proposed in the literature, to generate an index of international Internet adoption and, secondly, by applying the fuzzy theory, to propose a method for calculating the digital divide by assigning weights to each item value of the index, offering an alternative method of analysis.

2. Measures of the digital divide

Several authors in the literature have evaluated the digital divide, but the methods have varied in the measurement variables and concepts used. Early studies analysed the digital divide through four concepts: motivational access, material access, skill access, and usage access (van Deursen & van Dijk, 2013; van Dijk & Hacker, 2003). Motivational access refers to the wish to have a computer and to be connected to information technology (IT) (Ghobadi & Ghobadi, 2013); material access concerns the lack of technological infrastructure and possibilities to access it; skill access includes operational skills (software and hardware), information skills (the ability to process information), and strategic skills (strategic applicability of use for the individual and social good); and, finally, usage access is largely linked to the demographic characteristics of users and connections (van Dijk, 2006). The model of "access gaps" should be taken into account. Subsequent authors grouped the analysis of the digital divide into three states (Dewan & Riggins, 2005; Wei, Teo, Chan, & Tan, 2011). The first initial level of access to IT is software and hardware access; from this perspective the digital divide is caused by two types of factors, technological access and social access. First is the degree of access that a person has to computers and the Internet, while, social access refers to the involvement in the socioeconomic condition for the use of IT (Warschauer, 2003). The second level, degree of skill in the use of IT, means that, to participate in the digital society, one should at least have basic IT knowledge and ability to use computers and be connected to the Internet (Chang et al., 2015). Finally, to evaluate the achievement of outcomes in its use, the final stage is online participation, referring to any general user behaviour to participate and interact with other people through various Internet services (Chang et al., 2015). With this model some authors have proposed casual interrelations between various indicators, concurring with the concept of dynamic interactions between access gaps (Barzilai-Nahon, 2006; Wei et al., 2011). In these aggregate studies, taking a country as a unit of measure, the digital divide can be examined as the sum of the other gaps (Zwillenberg et al., 2014), in which the macroeconomic indicators that are most commonly used are those that concern the access to and use of ICTs (factors of the technological gap) or the level of income and wealth distribution (social gap) (Ramírez & Gutiérrez, 2008). Most of the institutions dedicated to the study and improvement of the digital divide have had an impact on the methods of collecting statistical information and generating indicators, which are used today to build international indices, such as the ICT Development Index (ITU) or the Index Information Society (ISI).

This paper proposes a new index to measure the digital divide of several countries based on multiple indicators. The literature contains particular studies on some indicators, for example the study by Hilbert (2016), which examined two digital divide access indicators and concluded that it is necessary to consider indicators that measure each of the possible levels of the digital divide from physical access to usability and web production (Pick, Sarkar, & Johnson, 2015). According to the study by Ghobadi and Ghobadi (2013), four dimensions are proposed to group all the items used in the analysis of the digital divide.

Context Country (Context-Related)

Regarding the sources of adoption, such as trade barriers, access to capital, and regulations, these concepts contribute to the digital divide by influencing motivational issues (Ghobadi &

Ghobadi, 2013; Zwillenberg et al., 2014). For example, the availability of scientists and engineers is positive in the use of ITCs and the Internet (Pick & Nishida, 2015).

Aptitude (Motivation-Related)

This group refers to the wish to have a computer and to be connected to ICTs (Ghobadi & Ghobadi, 2013); the factors explaining motivational access are social, cultural, and human behaviours. These are directly related to the digital divide, especially for Latin America, and are determinants between technologies.

Competency (Skills-Related)

This includes the capacity to work with hardware and software, the capacity to use a computer, and all the indicators of physical access (Ghobadi & Ghobadi, 2013); for example, the indicators "subscription to mobile cellular and/or fixed broadband Internet" and "fixed quality and mobile broadband download speed measured by mean" were evaluated as feasible, suitable, and very relevant to measuring the digital divide (Hilbert, 2016).

Outcomes (Usage-Related)

This group is about the differential use of ICTs: active or creative use, regarding contributions to the Internet by users themselves; and passive use, receivers of that software and hardware from active users (Ghobadi & Ghobadi, 2013). The indicators concern the use of the Internet and relate to the usability of the network, and different authors have grouped them into categories like instrumental, creative, and networking skills (Lee, Park, & Hwang, 2014).

TABLE 1. MEASUREMENT INDEX

Context Country-Related (Context Access)	**Aptitude- Related (Motivational Access)**	**Competency - Related (Skill Access)**	**Outcomes-Related (Usage Access)**
Labour*:** - Availability of qualified engineers (0-7) (WEF) - Availability of research and training services (0-7) (WB) Availability of scientists and engineers (0-7) (WB)	**Ability***:** - Quality of education system (0-7) (WEF) - Availability of latest technologies (0-7) (WB) - Secondary Education gross enrolment rate (%) UNESCO - Tertiary Education	**Access***:** - Individuals using internet (%) (WB) - Internet users (per 100 people) (WB) - Fixed broadband internet subscriptions /100 people - Mobile telephone subscriptions/100 people	**Social Usage**:** - Use of virtual social networks, 1-7 (best) (WEF) - E-Participation Index, 0–1 (UNDESA) **Governance Usage*:**

Capital*: - Availability of financial services (0-7) (WB) - Affordability of financial services (0-7) - Ease of access to loans (0-7) (WB) **Infrastructure***:** - Quality of overall infrastructure (0-7) WEF	gross enrolment rate (%) UNESCO **Access chindren***:** - Internet access in schools (0-7) **Trust*:** Secure Internet servers (per 1 million people)	Mobile broadband subscriptions/100 people - Mobile network coverage, % pop.(ITU) - Households w/ personal computer, % (ITU) - Households w/ Internet access, % (ITU) **Speed*:** - International internet bandwidth, kb/s per user **Price*:** - Prepaid mobile cellular tariffs, PPP $/min. - Fixed broadband Internet tariffs, PPP $/month - Internet & telephony competition, 0–2 (best) WEF	**-** Government Online Service Index, 0–1 (UNDESA) **ICT Usage*:** - PCT patents, applications/milli on pop. (WEF) - ICT PCT patents, applications/milli on pop. (WEF) **Business Usage***:** -Business-to-business Internet use, 0-7 (WFE) -Business-to-consumer Internet use, 1-7 (WEF)

* Low importance, ** Medium importance, *** High importance

3. Methodology

To construct an index to measure the digital divide in a number of countries and compare them, the joint use of fuzzy logic and distances is proposed.

The weighted Hamming distance (WHD) is a useful tool to compare a set of countries with the ideal based on a set of indicators (Figueira, Greco, & Ehrgott, 2005; Gil-Aluja, 1999; Gil-Lafuente, 2001; Merigo, 2013; Merigo & Gil-Lafuente, 2007; Zavadskas & Turskis, 2011).

First, fuzzy subsets are used to describe each of the countries. These subsets fuzzy are composed of 33 indicators of the digital divide, which are grouped into 3 dimensions related to the country context (labour, capital, and infrastructure), 3 related to skills (ability, access, and trust), 3 related to skills (Internet access, speed, and price), and 4 related to the results of use (social, ICT, B2B, and governance).

$$A_i = \begin{array}{|c|c|c|c|} \multicolumn{1}{c}{C_1} & \multicolumn{1}{c}{C_2} & \multicolumn{1}{c}{\ldots} & \multicolumn{1}{c}{C_{33}} \\ \hline \mu_{C1}^{(i)} & \mu_{C2}^{(i)} & \ldots & \mu_{C33}^{(i)} \\ \hline \end{array} \quad (1)$$

Second, because the information available is in different units of measurement, we proceed to normalize the data matrix to work with comparable data using the following formula:

$$n_{ij} = \frac{x_{ij}}{\sqrt{\sum_{j=1}^{m}(x_{ij})^2}} \quad (2)$$

$$i = 1, \ldots, m; \; j = 1, \ldots, n$$

Third, the fuzzy subsets described above are used to complete the membership characteristic functions of each of the countries that make up benchmark set A (Kaufmann & Gil-Aluja, 1986). For this we use the normalized information obtained from secondary sources such as the World Economic Forum, the World Bank, and the United Nations. Referential set A is composed of seventeen Latin American countries: Argentina, Brazil, Colombia, Costa Rica, Chile, El Salvador, Guatemala, Haiti, Honduras, Nicaragua, Panama, Paraguay, Puerto Rico, Peru, Uruguay, and Venezuela. In addition, a fictional country is introduced to collect the ideal levels of indicators to avoid the digital divide. It represents the case of a country in which all the levels of the indicators are maximums, that is, a country with a digital divide of 0, although this situation may not be true for any country.

$$A = \{A_1, A_2, A_3, \ldots, A_{17}, A^*\} \quad (3)$$

Fourth, the weights of each of the indicators are obtained. From the information in previous studies (Dewan & Riggins, 2005; Ghobadi & Ghobadi, 2013; Hilbert, 2016; Lee et al., 2014; Pick et al., 2015; Ramírez & Gutiérrez, 2008; van Dijk & Hacker, 2003; Wei et al., 2011), an importance level is assigned to each sub-dimension and dimension to obtain a weighting coefficient for each of the indicators that make up the fuzzy subset. To avoid sub-indicators in size with a larger number of items, the use of a diluted importance convex weighting coefficient (Arroyo-Cañada & Gil-Lafuente, 2012) is proposed. This requires taking the level of importance assigned to existing previous studies in the literature on the digital divide and, through an expert opinion, proposing the importance of each of the indicators (p_{ij}). From these average levels of importance for each of the dimensions, (k_j) is obtained as follows:

$$k_j = \frac{\sum_{n=1}^{i} p_{ij}}{n_j} \quad (4)$$

From the average size (k_j), the importance of the main dimensions (K_j) is obtained, such that:

$$K_j = \frac{k_j}{\sum_{j=1}^{n} k_j} \tag{5}$$

From the importance of the main dimensions (K_j), the coefficient of convex weighting is obtained for each of the items of different dimensions (ω_{ij}), weighting the average importance of each of the items within the dimension of the importance of each of the dimensions:

$$\omega_{ij} = k_j \times \frac{p_{ij}}{\sum_{n=1}^{i} p_{ij}} \tag{6}$$

In this case it is based on uncertain information about the importance of each of the dimensions used, as it was collected through linguistic indicators of three degrees of importance (low, medium, and high). Therefore, it is necessary to transform these linguistic indicators into triangular fuzzy numbers through a process of defuzzification to obtain:

Low importance = (0, 0.167, 0.333)
Medium importance = (0.334, 0.5, 0.667)
High importance = (0.668, 0.834, 1)

Given the expert opinion, and to simplify the analysis, it is proposed to use the average values of these triangular numbers, so (0.167, 0.5, 0.834) will be used as weighting values for the three grades of importance (low, medium, and high), respectively.

Finally, the distances are calculated for the ideal level (digital divide 0) using the characteristics of membership functions. For this we choose the Hamming distance, since none of the countries have ideal levels of indicators and because we can easily solve the exercise raised in this research using characteristic membership functions as values.

$$dH_i(A_i, A^*) = \sum_{i=1}^{n} \omega_{ij} \left|\mu_{A_i}(x_{ij}) - \mu_{A^*}(x_{ij})\right| \tag{7}$$

where $x \in \forall i = 1,2, \dots, n; x \in \forall j = 1,2, \dots, k; \sum_{i=1, j=1}^{n,k} \omega_{ij} = 1$

4. Results

First, Table 2 describes each of the countries by fuzzy subsets from the 33 selected indicators of the digital divide.

TABLE 2. FUZZY SUBSETS OF COUNTRIES

	Usage Access)		
	B2B usage		Governance Usage
	C31	C32	C33
Argentina	4,08	4,32	0,55
Brazil	4,62	5,12	0,60
Chile	5,34	5,12	0,82
Colombia	4,81	4,65	0,79
Costa Rica	5,14	4,77	0,61
El Salvador	4,69	4,93	0,54
Guatemala	4,89	4,86	0,15
Haiti	3,54	3,48	0,11
Honduras	4,90	4,55	0,40
Mexico	4,69	4,22	0,66
Nicaragua	3,90	3,48	0,09
Panama	5,01	5,13	0,37
Paraguay	3,92	4,11	0,23
Peru	4,65	4,28	0,63
Puerto Rico	5,47	5,24	0,72
Uruguay	4,36	4,34	0,85
Venezuela	3,91	3,99	0,55

Second, the normalized data matrix (Table 3) is obtained:

TABLE 3. NORMALIZED DATA MATRIX

	Context Country-Related (Context							Aptitude-Related (Motivational Access)							Competency-Related (Skill Access)												Outcomes-Related (Usage Access)						
	Labour			Capital			Infraestructure	Ability				Access		Trust	Access								Speed	Price			Social usage		ICT Usage		B2B usage		Governance Usage
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24	C25	C26	C27	C28	C29	C30	C31	C32	C33
Argentina	0,25	0,25	0,25	0,16	0,15	0,17	0,19	0,25	0,20	0,27	0,37	0,24	0,14	0,19	0,32	0,32	0,34	0,32	0,15	0,25	0,34	0,36	0,20	0,25	0,23	0,25	0,21	0,26	0,14	0,12	0,21	0,23	0,24
Brazil	0,21	0,26	0,21	0,28	0,23	0,29	0,20	0,23	0,24	0,29	0,21	0,22	0,23	0,24	0,27	0,28	0,25	0,27	0,48	0,26	0,28	0,29	0,20	0,40	0,11	0,25	0,27	0,26	0,38	0,22	0,24	0,27	0,26
Chile	0,30	0,26	0,30	0,29	0,31	0,28	0,30	0,29	0,29	0,26	0,35	0,30	0,30	0,45	0,35	0,36	0,30	0,27	0,33	0,25	0,33	0,34	0,26	0,16	0,32	0,25	0,36	0,26	0,74	0,33	0,28	0,27	0,35
Colombia	0,25	0,24	0,25	0,25	0,24	0,21	0,22	0,25	0,23	0,27	0,21	0,24	0,23	0,17	0,27	0,26	0,23	0,21	0,07	0,26	0,24	0,24	0,35	0,16	0,19	0,25	0,34	0,24	0,14	0,08	0,25	0,25	0,34
Costa Rica	0,31	0,29	0,31	0,23	0,19	0,24	0,23	0,32	0,26	0,30	0,22	0,28	0,31	0,35	0,24	0,24	0,24	0,29	0,67	0,18	0,30	0,32	0,34	0,05	0,13	0,21	0,31	0,26	0,15	0,14	0,27	0,25	0,26
El Salvador	0,24	0,26	0,24	0,22	0,25	0,23	0,29	0,26	0,22	0,20	0,12	0,24	0,25	0,08	0,12	0,15	0,11	0,27	0,06	0,25	0,13	0,09	0,19	0,16	0,19	0,24	0,23	0,23	0,01	0,00	0,25	0,26	0,23
Guatemala	0,23	0,26	0,23	0,28	0,26	0,29	0,29	0,22	0,27	0,19	0,09	0,20	0,26	0,06	0,10	0,12	0,04	0,28	0,04	0,26	0,11	0,06	0,05	0,35	0,34	0,25	0,07	0,24	0,01	0,00	0,26	0,26	0,06
Haiti	0,19	0,16	0,19	0,16	0,20	0,17	0,14	0,18	0,19	0,20	0,17	0,15	0,16	0,01	0,06	0,06	0,00	0,14	0,00	0,13	0,05	0,03	0,00	0,13	0,56	0,25	0,07	0,20	0,00	0,00	0,19	0,19	0,05
Honduras	0,23	0,23	0,23	0,27	0,25	0,24	0,22	0,22	0,25	0,21	0,10	0,21	0,26	0,04	0,09	0,09	0,02	0,19	0,11	0,24	0,12	0,11	0,05	0,21	0,22	0,25	0,13	0,24	0,00	0,00	0,26	0,24	0,17
Mexico	0,25	0,25	0,25	0,23	0,21	0,21	0,27	0,22	0,25	0,25	0,14	0,22	0,24	0,12	0,23	0,22	0,28	0,17	0,06	0,26	0,21	0,21	0,10	0,07	0,13	0,25	0,23	0,23	0,20	0,12	0,25	0,23	0,28
Nicaragua	0,20	0,19	0,20	0,20	0,24	0,22	0,21	0,20	0,20	0,20	0,09	0,18	0,20	0,04	0,08	0,09	0,05	0,22	0,01	0,26	0,06	0,06	0,15	0,60	0,30	0,24	0,04	0,20	0,02	0,04	0,21	0,19	0,04
Panama	0,25	0,25	0,25	0,30	0,34	0,31	0,32	0,27	0,29	0,24	0,20	0,31	0,25	0,42	0,23	0,22	0,19	0,32	0,23	0,25	0,23	0,21	0,25	0,12	0,11	0,25	0,19	0,26	0,23	0,72	0,26	0,27	0,16
Paraguay	0,17	0,18	0,17	0,23	0,25	0,21	0,17	0,18	0,20	0,20	0,16	0,17	0,24	0,09	0,20	0,21	0,04	0,21	0,04	0,26	0,18	0,18	0,06	0,19	0,24	0,25	0,10	0,22	0,00	0,00	0,21	0,22	0,10
Peru	0,21	0,23	0,21	0,25	0,27	0,24	0,22	0,21	0,24	0,26	0,20	0,22	0,21	0,10	0,21	0,20	0,13	0,19	0,03	0,26	0,19	0,15	0,08	0,18	0,23	0,25	0,27	0,22	0,03	0,04	0,24	0,23	0,27
Puerto Rico	0,34	0,33	0,34	0,29	0,24	0,30	0,31	0,28	0,31	0,23	0,41	0,28	0,33	0,46	0,39	0,39	0,40	0,17	0,15	0,18	0,35	0,41	0,63	0,07	0,15	0,25	0,32	0,28	0,24	0,41	0,29	0,28	0,31
Uruguay	0,22	0,24	0,22	0,23	0,24	0,24	0,26	0,27	0,24	0,26	0,30	0,36	0,29	0,34	0,31	0,30	0,52	0,31	0,30	0,26	0,39	0,36	0,28	0,21	0,10	0,13	0,37	0,26	0,30	0,32	0,23	0,23	0,37
Venezuela	0,21	0,18	0,21	0,19	0,20	0,22	0,17	0,22	0,19	0,25	0,37	0,21	0,09	0,04	0,29	0,28	0,18	0,20	0,03	0,24	0,24	0,21	0,05	0,13	0,08	0,25	0,22	0,26	0,03	0,01	0,21	0,21	0,24

To obtain the weights of each of the indicators, the average of each dimension (k_j) is obtained. An example of the resolution of the first dimension is described as follows:

$$k_j = \frac{\sum_{n=1}^{i} p_{ij}}{n_j} = \frac{8.34+8.34+8.34+1.67+1.67+1.67+8.34}{7} = 5.48 \tag{8}$$

The average importance to the four main dimensions would be k_j = (5.48, 7.39, 6.12, 4.53). Thus, the importance of each of the dimensions is obtained by dividing each of these averages by the total amount, such that if the first dimension is:

$$K_j = \frac{k_j}{\sum_{j=1}^{n} k_j} = \frac{5.48}{5.48+7.39+6.12+4.53} = 0.233 \tag{9}$$

the major vector of the main dimensions K_j = (0.233, 0.314, 0.260, 0.193) is obtained.

From the importance of the main dimensions (K_j), the convex weighting coefficient for each of the items of different dimensions (ω_{ij}) is obtained. In the case of the first indicator the following is obtained:

$$\omega_{ij} = k_j \times \frac{p_{ij}}{\sum_{n=1}^{i} p_{ij}} = 0.233 \times \frac{8.34}{8.34+8.34+8.34+1.67+1.67+1.67+8.34} = 0.05 \tag{10}$$

In the same way, one can obtain the 33 coefficients composing the convex weighting vector:

$$\omega = (0.05, 0.05, 0.05, 0.01, 0.01, 0.01, 0.05, 0.05, 0.05, 0.05, 0.05, 0.05, 0.05, 0.01, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.03, 0.01, 0.01, 0.01, 0.01, 0.01, 0.01, 0.03, 0.03, 0.05, 0.05, 0.01) \tag{11}$$

Finally, Hamming distances are obtained with respect to the ideal level (digital divide 0) using the characteristic functions of belonging to each of the countries analysed. In the case of Argentina (A_1), the following is obtained:

$$dH_1(A_1, A^*) = 0.757 \quad (12)$$

If we calculate the distances for each country considered for this investigation and order them from major to minor, a ranking of the countries is obtained depending on their level of the digital divide, as shown in Table 4.

TABLE 4. RANKING OF COUNTRIES BY DIGITAL DIVIDE INDEX

Country	Distance
Haiti	0,866
Nicaragua	0,841
Paraguay	0,829
Honduras	0,819
Guatemala	0,811
Venezuela	0,805
El Salvador	0,802
Peru	0,800
Mexico	0,780
Colombia	0,770
Argentina	0,757
Brazil	0,744
Panama	0,730
Costa Rica	0,726
Uruguay	0,717
Puerto Rico	0,690
Chile	0,685

The distances indicate how away from the ideal each of the countries analysed is, so that the countries occupying the first positions are those with a greater digital divide, while those countries in the last positions of the ranking indicate a lesser digital divide. In view of the results, we can say that Haiti is the country with the largest digital divide, while Chile is the country with the lowest digital divide (Table 4).

Making a more specific analysis, we examine the ranking for each of the groups of the proposed indicators. First, for the group of indicators called Context, only Puerto Rico is close to the desired level, 0.675 away, 13 countries have distances nearing to 0.7, and the farthest away are Venezuela, Paraguay, and Haiti. These results are of special concern because of their importance in relation to the technical conditions that support the development of ICT and the Internet, especially the conditions that encourage investment on the one hand and indicators of investment in infrastructure, and qualified professionals in the sector on the other (Table 5).

For the pillar called Aptitude, Puerto Rico is again the first country to approach the optimum point with 0.688; again it is followed by a homogeneous group of 14 countries within the margin of 0.7 points and finally by the 3 countries Paraguay, Nicaragua, and Haiti. As in the previous case, in this group of indicators the Latin American countries are far from the ideal, given that the aspects that these indicators measure are related to the quality of education, adding more specific indicators of training in ICT and the Internet in school and university students as well as factors that motivate its use, such as security policies on Internet use (Table 5).

The third group of indicators, called Competency, shows the best Latin American countries in relation to the desired optimum, because seven countries are in the range of 0.5 points, headed by Uruguay and followed by Puerto Rico, Costa Rica, Chile, Argentina, Brazil, and Panama. These are followed by eight countries led by Colombia in the range of 0.6 and 0.69, and the farthest away are Nicaragua and Haiti. In this pillar the classic indicators of the digital divide are analysed, as are access, the Internet speed, and the cost of use (Table 5).

Finally, regarding the outcome-related indicators, concerning the social use of ICT and Internet-related recreational uses, services, commerce, government and others, the results show that only three countries are within 0.6 points of the optimal value (Chile, Panama, and Puerto Rico), followed by five countries in the range of 0.7 points and finally nine countries in the range of 0.8 points, starting with Argentina and ending with Haiti; thus, the Latin American region is very far from the optimum point for this group of indicators (Table 5).

TABLE 5. Ranking by Indicators Dimensions

Context			**Aptitude**			**Competency**			**Outcomes**	
Countries	Distances		Countries	Distances		Countries	Distances		Countries	Distances
Haiti	0,831		Haiti	0,829		Haiti	0,729		Haiti	0,885
Paraguay	0,821		Nicaragua	0,826		Nicaragua	0,707		Nicaragua	0,874
Venezuela	0,806		Paraguay	0,810		Honduras	0,699		Paraguay	0,865
Nicaragua	0,795		Guatemala	0,799		Guatemala	0,694		Venezuela	0,846
Argentina	0,777		Honduras	0,799		El Salvador	0,679		Guatemala	0,842
Peru	0,776		El Salvador	0,789		Paraguay	0,665		Honduras	0,840
Brazil	0,773		Venezuela	0,784		Peru	0,661		El Salvador	0,828
Honduras	0,768		Mexico	0,783		Mexico	0,635		Peru	0,823
Uruguay	0,767		Peru	0,781		Venezuela	0,624		Argentina	0,804
Colombia	0,761		Brazil	0,764		Colombia	0,607		Mexico	0,787
Mexico	0,747		Colombia	0,763		Panama	0,598		Colombia	0,785
Guatemala	0,746		Argentina	0,755		Brazil	0,539		Costa Rica	0,773
El Salvador	0,745		Panama	0,735		Argentina	0,535		Brazil	0,728
Costa Rica	0,726		Costa Rica	0,717		Chile	0,520		Uruguay	0,728
Panama	0,726		Uruguay	0,712		Costa Rica	0,516		Puerto Rico	0,699
Chile	0,709		Chile	0,694		Puerto Rico	0,512		Panama	0,677
Puerto Rico	0,674		Puerto Rico	0,688		Uruguay	0,504		Chile	0,634

5. Conclusions

This article was first intended to propose an index to group a number of related measures of the digital divide indicators. The results have generated a robust index composed of 33 indicators that represent the 4 main pillars of the digital divide. Therefore, the index presented manages to integrate the different forms and scales on the digital divide, from the basic digital divide and access to the digital generation gap usability, content, and software.

Second, using this index the digital divide was measured for seventeen Latin American countries, reaching the major conclusion that the country that best approaches the ideal situation of a zero digital divide, taking into account the four pillars, is Chile. The first level of countries where the gap is smaller contains Chile and Puerto Rico are the only countries that are at the range (0.6, 0.69). This result is consistent with the development of the Internet and TICs for these two countries. Chile is one of the countries leading the development of the Internet and telecommunications in South America, especially regarding the adoption of the Internet, with coverage of 70% for 2013 (Katz et al., 2015). Puerto Rico is a country that for the last 5 years has been following a special regime, supported by the US, to implement an action plan to reduce the level of the digital divide, and this is reflected in the results. In the subsequent range (0.7, 0.79) are Uruguay, Costa Rica, Panama, Brazil, Argentina, Colombia, and Mexico. Costa Rica and Colombia stand out and show that their current policies to reduce the digital divide are effective, while Mexico is in contrast, since for some items it could be a country with a high digital divide (for accessibility it had only 10% broadband penetration in 2013) while in other aspects it has advanced development, such as Internet tariffs in relation to the per capita GDP (Breu, Guggenbichler, & Wollmann, 2012). Finally, the group of countries with a greater digital divide (0.8, 0.89) are Peru, El Salvador, Venezuela, Guatemala, Honduras, Paraguay, Nicaragua, and Haiti. These countries have serious problems in the availability and use of ICT. Managers of the technological and social areas of the governments of these countries should take action to reduce the digital divide.

The set of fuzzy logic and weighted Hamming distance usage was effective in measuring the digital divide based on information from secondary sources. The digital divide is important on the social, economic, and political levels, so this paper sheds light for decision makers in those areas to adapt their policies to the global technological reality. The proposed index allows the different indicators used for free public access to be updated annually, so it is a dynamic tool that enables the monitoring of countries to meet their level of the digital divide and to correct the necessary aspects depending on each of the groups of indicators. It also enables international companies and organizations to have an overview of the development of the Internet and ICT in each country to make investment decisions and monitor trade favourably to their interests in the area. While this index applies to countries where this information is collected, and excluded important countries of the region as Ecuador, the results have proved that the measurement is reliable and approaches the reality of the context in the area.

Future research may undertake longitudinal studies to develop the knowledge of the impact of government policies on reducing the digital divide and to determine which aspects are more related to changes in the index.

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