Abstract: Achieving sustainable economic development is one of humanity’s greatest challenges, and, in this regard, the United Nations has promoted a line of research based on sustainable economic development. In view of this, our study focused on the sustainable economic development of nations, specifically, development through the deployment of information and communication technologies (ICTs). Academic researchers recognize the importance of ICT for economic and sustainable development, but there is controversy in the literature regarding two opposing points of view. First, there is a view that advances in ICT support Gross Domestic Product (GDP) growth, while, on the other hand, the view is that there is no relationship between these two factors. In view of this, we conducted a study where the objective was to determine whether investing in ICT contributes to sustainable economic development (measured by the GDP per capita) of European Union countries. We used Eurostat data and applied the partial least-squares (PLS) method to address the study. This approach allowed us to analyze European Union countries from 2014 to 2017, using fairly rigorous data. The most outstanding result was that ICT accounted for most of the explained variance in GDP per capita (GDPpp), and, specifically, the most representative indicator was “digital public services.” Therefore, we concluded that investing in the deployment of ICT supports the sustainable economic development of European Union countries. These countries should focus on investing in improved connectivity in areas with poor communications, as well as in training area inhabitants in the use and development of ICT to obtain greater development using these tools and technologies.

Keywords: ICT; sustainable development; GDPpp; European Union; PLS

1. Introduction

Information and communication technologies (ICTs) are essential for reducing poverty, improving health and education services, and creating income sources for the most disadvantaged. Thus, the role of these technologies is to drive economic development and to enhance social development and the promotion of human rights and democracy [1].

The literature reveals a trend toward promoting sustaining consumption or per capita income that does not decrease over time, and this is called the weak sustainability approach [2–6]. Some authors have included the criterion of equity in distribution under this concept [7]. However, this approach promulgates maintaining the reproductive capacity of the economic system, with the aim of sustaining growth rates in GDP per capita.

Anand and Sen [8,9] share Solow’s point of view, which states that sustainability is a matter of equity in distribution, i.e., it is about sharing well-being between people of the present and those of the future. The authors agree that keeping productive capacity intact is not the same as leaving the planet as it is today. Given this, we need to preserve the opportunities of future generations.
However, according to the works of Hartwick [10,11] and Hanley [12], the environmentally adjusted gross domestic product is a good measure of sustainable development. It is useful when all the elements are valued correctly and when it is based on the economic situation of the moment. The assessment is also accurate for future predictions that relieve shortages in the coming periods, and the depreciation of natural capital is considered. In this way, an economy is deemed sustainable if this value does not decrease.

Along these lines, the UN generated a set of “Sustainable Development Indicators” [13]. Within these indicators, we find an economic block, and, within this block, we find the gross domestic product per capita (GDPpp) [13] (p. 15) as a descriptor of sustainable development [14].

If we focus on the GDP per capita, we must comment that the existing literature has identified a link between the GDPpp and ICT [15–17]. As a result, the effect of deploying ICT provides support for the economic development of nations [18,19], and some specific authors indicate that investments in ICT boost productivity [20,21].

To examine the influence of ICT on sustainable economic growth, several existing studies have been based on the exogenous growth model [22,23].

On the contrary, there is another line of thinking that questions the positive associations between ICT and economic performance. Although most of the research that studies the link between ICT and economic growth suggests a positive relationship, other studies have reported null relationships in terms of significance [24–28]. Thus, the results are far from homogeneous.

Therefore, given the research problem posed by the lack of consensus in the literature regarding the impact of ICT on economic growth [27], and the need for sustainable economic development over time, we consider it appropriate to ask the following research question: Does the deployment of ICT positively influence the economic development of countries through GDP growth per capita? To answer this research question, we analyzed the impact of ICT on the growth in GDP per capita of European Union countries.

To achieve our objective, we measured the use of ICT using data provided by Eurostat. The use of this base is appropriate for two reasons. First, it consists of a large number of indicators, so it is not only a means to verify the possible existence of the effect of ICT on economic growth, but it also makes it possible to arrange the group of ICT indicators that contribute most to the economic development of nations. This allowed us to predict whether the five constructs analyzed provide a positive variance, which is the most outstanding result. From the results, “digital public services” had the greatest impact on the development of GDP per capita. Therefore, it is the one with the highest impact on economic development.

Next, we will present the theoretical framework, the empirical framework, the results, a discussion of the results, and, lastly, the conclusions, limitations, and future lines of research.

2. Theoretical Framework

We will begin by examining the concept of the United Nations Commission on Sustainable Development (UNCSD). First, we must indicate that the UNCSD defines sustainable development as “development that meets current needs without compromising the ability of future generations to meet their own needs” [13].

However, the most widespread definition of “sustainable development” is the one from the Brudtland Commission [29] (p. 8), which defines it as “progress that meets current needs without compromising the ability of future generations to meet their own needs.”

Additionally, Reference [30] defines the concept of “sustainable development” as the persistence of the integrity and structure of a system over time.

For us, the key point on which this research was based is the “weak sustainability” approach initiated by Reference [9], which notes that “sustainable development” should not let consumption or per capita income decrease over time [2–6,8,9], with equal distribution provided among the population [7].
Thus, in 1995, the United Nations Commission on Sustainable Development approved the Work Program on Sustainable Development Indicators, and the result was the Sustainable Development Indicators Chart [13]. In this report, we find the GDP per capita to be an indicator of Sustainable Development, belonging to the Economic Activity sub-theme, which falls within the Economic Structure Theme [13,14] (p. 15), (p. 223) and allows us to focus our research on the development of this indicator.

2.1. ICT and Sustainable Environment

As indicated in the introduction, international organizations such as the Organisation for Economic Co-operation and Development (OECD) assign a decisive role to ICT in achieving sustainable development, especially to reduce poverty and to promote social equality and democracy [1].

From a more academic point of view, it is possible to find researchers who stress the importance of ICT to achieve sustainable growth objectives. For example, Bhujabal & Sethi (2019) [31] (pp. 1–2) point out a number of benefits derived from ICT, among which we highlight: (a) global integration, which allows developing countries to adopt and benefit from the technologies of developed countries, (b) the ability of these technologies to overcome both geographical and cultural barriers, which promotes convergence between advanced and non-advanced economies, (c) promotion of government transparency by reducing corruption, and (d) access to new opportunities and information for the population.

Along the same lines, Toader, Firtescu, Roman, and Anton [32] identify a number of investigations that show the positive impacts of ICT on the economy as a whole. For our study, we chose those directly related to sustainable development (Table 1).

| Impact of ICT on Sustainability                                                                 | Author |
|------------------------------------------------------------------------------------------------|--------|
| Promotion of sustainable development of entrepreneurship and small and micro enterprises: it   | [33]   |
| improves financing by reducing information asymmetry and reducing the cost of the agency.      |        |
| Cohesion in regional differences.                                                              | [34]   |
| Quick and easy access to information not only for economic agents, but also for the whole society. | [35]   |
| Access of human capital through teleworking                                                   | [36]   |
| Fast and effective business communication: reducing costs and increasing productivity.          | [37]   |

Source: Toader, Firtescu, Roman, and Anton (2018) [32].

It is also possible to find examples beyond the traditional parameters such as economic development. In the field of education, Kim’s work [37] emphasizes the capacity of ICT to reduce inequalities in education. Specifically, his study showed how the application of ICT was useful for reducing the gap between immigrant and non-immigrant students in the United States.

2.2. ICT and the Environment

Information and communication technologies are given key roles in the environment by some academics. These technologies are of vital importance, not only for economic growth but also for environmental sustainability, since they are capable of reducing carbon emissions [38]. By applying them, it is possible to protect the environment and to promote environmental sustainability and rural sustainable development [39]. In addition, “they have enriched people’s daily lives, providing users with great freedom” [40] (p. 16).

An example of the importance that researchers give to ICT regarding sustainability is shown in studies that have defined particular theoretical frameworks on ICT, whose objective is to achieve sustainable development [41].

However, the impact of information and communication technologies is not absolutely positive. In this sense, some academics assume a dual classification to describe the environmental effects of ICT. These effects can be direct and indirect [42,43]. The direct effects, which are also called first-order effects,
are related to the demand for materials and energy throughout the life cycle of the ICT product [44]. The direct effects refer to the resources used, the emissions caused by the production, and the use and disposal of ICT products [42]. Indirect effects, or second-order effects, reflect the result of applying ICT in other dimensions that involve environmental changes, such as changes in consumption [45,46]. One example of discussion generated by the environmental impact of ICT is found in Truby [47], where the author focuses on Bitcoin technology.

In any case, we find several empirical works that highlight the importance of ICT regarding sustainability. For example, the work of Batool et al. [38], focused on the South Korean economy, argues that ICT helps reduce environmental degradation over the medium and long-term. In his research on ICT and environmental protection, Ruth [48] concluded that it would be appropriate to adopt ICT to create green environments, which would result in reducing carbon emissions. This author based his work on the fact that ICT is essential for sectors related to waste processing, smart networks, or big data software. Moyer and Hughes [49] proposed the development of ICT infrastructures with the objective of reducing the cost of renewable energies and whose expected result would be a positive impact in terms of emissions. Therefore, with this measure, they predicted that total carbon emissions would be reduced in the long term (50 years according to their estimates). Jacob [50] studied the relationship between cities, climate change, and ICT. This author pointed out various concepts related to ICT as fundamental factors for reducing emissions, including smart logistics practices, smart buildings, and smart supply networks. Shabanpour, Golshani, Tayarani, Auld, and Mohammadian [51] explored the potential of teleworking in the city of Chicago by concluding that it can be a useful tool, not only for reducing traffic congestion in cities, but also for mitigating vehicle emissions. In the same line, Giovanis [52], in his Switzerland study during the period of 2002–2013, established that teleworking can be a tool that reduces traffic volume and improves air quality. Asongua, Rouxa, and Biekpeb [53] assessed the impact of ICT together with CO₂ emissions on inclusive human development in a study of 44 countries in sub-Saharan Africa during the years of 2000–2012. His research suggested that ICT can be used to mitigate environmental pollution in human development.

But how can ICT favor sustainable development? Batool et al. [38] (p. 25343) explained different ways in which ICT favors sustainability, and we can highlight the following as examples: (a) information systems [54], (b) big data applications [55], (c) energy efficiency and waste management [56], (d) sustainable smart cities [57], (e) low-carbon emissions [58], and (f) climate change education [59]. On the other hand, Andreopoulou [39] (pp. 2–3) identified four dimensions through which ICT promotes environmental sustainability: first, the reduction of emissions by applying ICT that optimizes energy use; second, an increase in environmental awareness through information dissemination, training, and education; third, through effective communication for environmental projects and networks; and, lastly, through sustainable environmental governance. This concept consists of promoting citizen participation in decision-making, which also motivates governments to be more responsible, transparent, and effective.

2.3. Growth Theories and ICT

Within this framework, researchers have linked ICT and economic growth, mainly based on the Exogenous Theory [19–21,60]. The scientific literature outlines the different means by which ICT generates economic growth and highlights the direct effects, which usually refer to productivity improvements, that arise explicitly from applying ICT [20,21,61–65].

On the contrary, we find authors who question the existence of a relationship between ICT and economic development [66–69]. In this study, we focused on whether the deployment of different ICT components was a realistic alternative to achieve sustainable economic development (measured by the GDPpp). Therefore, we find ourselves within the group of authors who claim that ICT improves economic development, and we propose the following hypotheses.
To study our objective, we established the general hypothesis that ICT influences sustainable economic growth. In this sense, we used the methodology of the European commission to measure ICT. Because ICT consists of five constructs in our methodology (connectivity, human capital, use of Internet, technological integration, and public services), we established a hypothesis for each of them.

**Hypothesis 1:** There is a causal and positive relationship between connectivity and economic development.

**Hypothesis 2:** There is a causal and positive relationship between ICT Human Capital and economic development.

**Hypothesis 3:** There is a causal and positive relationship between the Use of Internet and economic development.

**Hypothesis 4:** There is a causal and positive relationship between Technological Integration and economic development.

**Hypothesis 5:** There is a causal and positive relationship between Digital Public Services and economic development.

3. **Empirical Framework**

First, we will present the data used in the field study, and, then, we present the statistical technique used to test the hypotheses proposed in the theoretical section. The broad set of indicators used to measure ICT was grouped into five constructs (connectivity, human capital, use of Internet, technological integration, and public services) from the European Commission (see Appendix A). The variable used to measure economic development is GDP per capita, which was all obtained from Eurostat.

We considered that the variables of the model were COMPOSITE analyzed since they represent theoretical concepts that are measured through observable variables. In this case, authors such as Rigdon et al. [70] and Hair et al. [71] indicate the use of PLS for composite variables. In addition to carrying out the analysis, secondary or archival data were used. In this case, authors such as Gefen, Rigdon, and Straub [72] and Rigdon [73] justify the use of this technique.

Thus, the period analyzed was from 2014 to 2017, which gave rise to a sample of 112 cases that was used to build the data pool, where the sample unit is a country in a specific year.

The study was carried out in a European region. Therefore, the number of countries analyzed was not very large, which is why it can be considered that a small sample size has been used. In this case, the recommendations followed for this type of analysis were those by authors such as Richter et al. [74].

In addition, we eliminated indicators that had more than 15% of lost data, which complies with the above limitations, and the number of cases also comprised the entire sample [75].

Once we reached this point, and because the characteristics of our variables were continuous and secondary, the use of Partial Least-Squares (PLS) was considered appropriate [76-80].

Although the objective of the work analyzes the influence of some variables on the GDP, this tool enabled us to determine those variables that could predict the dependent construct. In this case, we wanted to identify the drivers of GDP behavior. Following Shmueli et al. [80] and Hair et al. [71], PLS supports predictive analysis. Predictive research will help us to carry out new observations at different moments in time and to be able to compare with the current results.

The structural equations approach allows us to test the hypotheses and, in addition, to analyze the contribution of each of the ICT constructs for economic development, which is why we provided a confirmatory analysis [72,73,75]. In short, the chosen technique will allow us to assess both the measurement model and the structural model in a unique, systematic, and integrative way with variance-based methods [72,81].

Lastly, SmartPLS was used (version 3.2.8) to predict latent variables based on the estimation of ordinary least-squares and principal component analyses. Thus, a causal-predictive analysis in complex situations was carried out, but only after obtaining theoretical information, such as in our case [75-84].
4. Results

To test the hypotheses using PLS, we conducted the study in three phases. First, we made an overall outline of the model. Second, we assessed the measurement model, in which we refined the indicators. Lastly, we assessed the structural model together by testing our hypotheses.

We started with a conceptual model (Figure 1) whose aim was to outline the indicators that made up the constructs of the overall model.

Regarding the evaluation of constructs, they were all of quality, and once the indicators with the lowest scores were refined, the results were consistent (see Table 2).

![Figure 1. Initial Model. Source: Own elaboration based on data obtained with SmartPLS software.](image)

Table 2. Construct reliability and validity.

| Reflective Construct | Cronbach’s Alpha | Rho_A | Composite Reliability | Average Variance Extracted | Discriminant Validity |
|----------------------|------------------|-------|-----------------------|----------------------------|-----------------------|
| 1_Connectivity        | 0.644            | 0.693 | 0.781                 | 0.549                      | YES                   |
| 2_Human Capital      | 0.915            | 1.043 | 0.957                 | 0.918                      | YES                   |
| 3_Use of Internet    | 1                | 1     | 1                     | 1                          | YES                   |
| 4_Tech. Integration  | 0.666            | 0.738 | 0.806                 | 0.585                      | YES                   |
| 5_Dig. Pub Services  | 0.827            | 1.080 | 0.867                 | 0.692                      | YES                   |
| GDP                  |                  | 1     |                       |                            | YES                   |

Source: Own elaboration based on SmartPLS.

After having evaluated the constructs of the proposed model with SmartPLS, and having eliminated the indicators that did not meet the SmartPLS quality criteria (see Table 3), we proceeded to analyze the significance of the proposed hypotheses.
Table 3. Parametric values justification.

| Analysis                | Parameter       | Values Higher Than | Justification |
|-------------------------|-----------------|-------------------|--------------|
| Individual reliability  | Loadings 0.4    | [84,85]           |              |
| Construct reliability   | Cronbach’s Alpha 0.7 | [86]             |              |
|                         | rho_A 0.7       | [87]              |              |
|                         | Composite Reliability 0.6 | [86,88] |              |
| Convergent validity     | Average variance extracted (AVE) 0.5 | [89,90] |              |
| Discriminant validity   | It compares the AVE with the correlations between constructs AVE > Correlations | [84,90] |              |
|                         | Heterotrait-monotrait ratio (HTMT) 0.85 | [77] |              |

Source: own elaboration based on Fernández-Portillo et al. (2016) [91], Fernández-Portillo et al. (2018) [92] Robina-Ramírez, Fernández-Portillo, and Díaz-Casero (2019) [93].

To test the hypotheses, we performed bootstrapping of 10,000 iterations. However, to validate a hypothesis, the sign of the path coefficient must be positive, which indicates that the results have the same direction as the hypothesis proposed. There is statistical significance measured by the t coefficient, and that confidence intervals do not contain zero (see Table 4).

Table 4. Results of hypothesis testing using the PLS technique.

| Hypothesis                          | Evaluation | Confidence Level | t-Statistic | Path Coefficient |
|-------------------------------------|------------|-----------------|-------------|-----------------|
| 1_Connectivity → GDP                | Accepted   | Yes             | 3.110 (****) | Yes (0.358)     |
| 2_Human Capital → GDP               | Accepted   | Yes             | 4.037 (****) | Yes (0.367)     |
| 3_Use of Internet → GDP             | Accepted   | Yes             | 3.272 (****) | Yes (0.188)     |
| 4_Tech. Integration → GDP           | Rejected   | Yes             | 2.691 (****) | No (-0.366)     |
| 5_Dig. Pub Services → GDP           | Rejected   | Yes             | 5.632 (****) | No (-0.436)     |

*** p (0.01), ** p (0.05), *p (0.1). One-tailed Student’s t test. Source: Own elaboration based on data obtained with SmartPLS.

Once the sample was analyzed, the hypotheses were tested and the model was validated (see Figure 2) by following the corresponding guidelines set by the PLS technique.

The results of the analysis indicated that hypotheses 1, 2, and 3 were accepted, with levels higher than 99% (see Table 4). Therefore, we can say that connectivity, human capital, and the use of the Internet had positive influences on GDP development, as seen through an improvement in GDP per capita. On the contrary, hypotheses 4 and 5, which refer to technological integration and the use of digital public services, were rejected. In this case, the reason for rejection was that the path coefficient was negative, even though the relationship was significant. This indicates the existence of a GDP relationship, which, while it could be interpreted as negative, when analyzing the correlation and the impact of the variance explained for each exogenous construct on the dependent construct (see Table 4), we can see that the contribution of both hypotheses to the GDP is positive. Digital public services contributed most to the explained variance of the model, which reached a value of 14.26%. Therefore, it should be studied in greater depth in future research. In addition, we can say that this model contained 42.6% of the explained variance of the GDP, corresponding, in this case, to ICT development. The value of $R^2$ was considered moderate, being between 0.33 and 0.67 [83]. In addition, the predictive capacity of the model was high at 0.359 [83].
Lastly, in Table 5, we can see the breakdown of the explained variance, the correlation between the constructs, and the results of the predictive relevance. In the case of this last parameter, according to Reference [94], a value of 0.359 was reached, which was an average value (Q2 > 0.25 y Q2 < 0.5).

Table 5. Evaluation of the R² level of the model.

| Hypothesis                        | R²  | Q²  | Path | Correlation | Variance Explained |
|-----------------------------------|-----|-----|------|-------------|--------------------|
| H1_Connectivity→GDP               | 0.358 | 0.305 | 10.92% |
| H2_Human Capital→GDP             | 0.367 | 0.224 | 8.22%  |
| H3_Use of Internet→GDP           | 0.188 | 0.205 | 3.85%  |
| H4_Tech. Integration→GDP         | -0.366 | -0.146 | 5.34%  |
| H5_Dig. Pub. Services→GDP        | -0.436 | -0.327 | 14.26% |
| ICT                              | 0.426 | 0.359 |        |

Source: own elaboration.

5. Discussion

The scientific literature has questioned the impact of ICT on economic growth. In our study, we analyzed the impact of these technologies on sustainable economic growth measured by GDP per capita. In this sense, we must emphasize that, contrary to authors who question the existence of a relationship between ICT and economic development [25,27,28], the most outstanding result shown in our study was that the five constructs analyzed provided a positive variance on the economic development of countries. Therefore, our results are aligned with research reporting that ICT generates economic growth in such a way that it improves productivity [20,61–64].

If we focus on the results obtained by each construct and hypothesis proposed, we see that hypotheses 1, 2, and 3, which refer to Connectivity, Human Capital, and the Use of Internet, respectively, were accepted with levels higher than 99%. Therefore, they have a positive influence on the economic development of countries. In addition, we can conclude that Connectivity contributed 10.92% of the explained variance of the GDP per capita, and Human Capital related to ICT contributed 8.22%. This is a clear indicator that countries that want to promote sustainable economic development must invest in...
improving connectivity in the most isolated areas and train their inhabitants how to use and develop ICT. On the contrary, hypotheses 4 and 5, which refer to technological integration and the use of digital public services, were rejected. However, this should be a motive for future research because the Student T test values were considered significant, and so is the impact from the explained variance. Thus, we see that the contribution to GDF of both constructs is positive. In this sense, and coinciding with the line marked by Kemp, Parto, and Gibson [93], it is necessary to indicate that digital public services was the construct that generated the highest contribution to the explained variance of the model, where it reached a value of 14.26%. Therefore, this should be studied in detail because this construct is directly controlled by the public administrations of countries. It is the indicator that is the easiest to enhance a priori by administrations in order to improve the sustainable economic development of a country.

Regarding the environmental impact of these technologies, as indicated in the theoretical framework, there is scientific debate over the costs and benefits of the generation and application of these technologies on the environment. It was not the objective of our research to study this environmental impact, but we consider it appropriate to comment on this controversy.

6. Conclusions

This paper analyzed the impact of ICT on sustainable economic development (measured by the GDPP). For this purpose, a study of European economies was carried out from 2014 to 2017. The main conclusion of our investigation is that the deployment of ICT can help realize sustainable economic development, at least within the European Union.

If we focus on the constructs analyzed, administrations should place special emphasis on opting for digital administration, which is followed by investment in connectivity and training in the area of ICT. Consequently, ICT offers countries a great opportunity to achieve sustainable economic development over time. In short, we can say that connectivity, human capital, and the use of the Internet positively influenced GDP development.

In addition, it is necessary to highlight that the “digital public services” construct was most representative of the variance, which reached a value of 14.26%. In this sense, the proposed model represents 42.6% of the explained variance of GDP per capita, which reached a level described by the statistical technique theory as moderate.

In short, as the most outstanding result, it is necessary to emphasize that the five constructs analyzed provide positive variances. Countries that want to promote sustainable economic development must invest in improving connectivity in the most isolated areas, and in training their population in the use and development of ICT, to obtain maximum performance from these tools and technologies.

On the contrary, relationships regarding the digital administration and technological integration with ICT have not been validated in our study, and these should be evaluated in alternative studies.

The main contribution of our study is the proposal of a structural model that shows the causal relationships between ICT variables and GDP. The model allows new variables to be incorporated into the proposed model in future studies by using the PLS technique.

As a limitation of this work, we can highlight that our sample was at the country level. It would be interesting to carry out the same study by analyzing the regions that make up the countries and, thus, compare the results of the less-developed regions with the more-developed ones.

Another limitation of our study is that it does not analyze the environmental impact of ICT, and the results and conclusions should be interpreted under a weak sustainability approach (measured by the GDPP).

With regard to future research, several studies can be carried out once we know in which aspects it would be interesting for more information to be collected and, therefore, studied. Therefore, we propose the following.

- It would be interesting to investigate in-depth the reasons why hypotheses 4 and 5 obtained a negative path when applying the PLS algorithm.
Lastly, it would be interesting to carry out the study at the regional level, by comparing the results of less-developed regions with more-developed regions to see if they contribute to sustainable development.

**Author Contributions:** Conceptualization, A.F.-P. and M.A.-G. Methodology, A.F.-P. Software, A.F.-P. Validation, A.F.-P., H.V.J.-N., and J.L.C.-P. Formal analysis, A.F.-P. Investigation, A.F.-P. and M.A.-G. Resources, A.F.-P. Data curation A.F.-P. Writing—original draft preparation, F.-P. and M.A.-G. Writing—review and editing, A.F.-P., M.A.-G., and H.V.J.-N. Visualization, A.F.-P. Supervision, A.F.-P., M.A.-G., H.V.J.-N., and J.L.C.-P. Project administration, A.F.-P.

**Funding:** This research received no external funding.

**Conflicts of Interest:** The authors declare no conflict of interest.

**Appendix A**

**Table A1.** ICT variables from the European Commission.

| CODE | DIMENSION/SUBCATEGORY/INDICATOR |
|------|----------------------------------|
| 1    | CONNECTIVITY                     |
| 1a   | Fixed broadband                  |
| 1a1  | Allocated spectrum for wireless broadband in EU harmonized bands |
| 1a2  | Speed                            |
| 1b   | Mobile bandwidth                 |
| 1b1  | Penetration of active mobile broadband users |
| 1b3  | Spectrum allocated to wireless broadband in EU harmonized bands |
| 1c   | Speed                            |
| 1c1  | Full broadband coverage of new generation access |
| 1c2  | Subscriptions of fixed broadband with speed \(\geq 30\) Mbps |
| 1d   | Affordability                    |
| 1d1  | Monthly Internet access rate with download speed above 12 and up to 30 Mbps (internet only) |
| 2    | HUMAN CAPITAL                    |
| 2a   | Basic skills and use             |
| 2a1  | Individuals who use Internet regularly |
| 2a2  | Individuals with basic or above basic digital skills |
| 2b   | Advanced skills and development  |
| 2b1  | Employed people with ICT specialist skills |
| 2b2  | Tertiary graduates in Science and Technology |
| 3    | USE OF INTERNET                  |
| 3a   | Content                          |
| 3a1  | Individuals who use the Internet to read online newspapers/magazines |
| 3a2  | Individuals who use the Internet to play or download games, images, films, or music |
| 3a3  | Households subscribed to some form of video-on-demand |
Table A1. Cont.

| CODE | DIMENSION/SUBCATEGORY/INDICATOR |
|------|---------------------------------|
| 3b   | Communication                   |
| 3b1  | Individuals who use the Internet to make video calls |
| 3b2  | Individuals who use the Internet to participate in social networks |
| 3c   | Transactions                    |
| 3c1  | Individuals who use the Internet for Internet banking |
| 3c2  | Individuals who use the Internet to order goods and services |
| 4    | TECHNOLOGICAL INTEGRATION       |
| 4a   | Digitalization of companies     |
| 4a1  | Companies that have enterprise resource planning (ERP) software packages to share information between different functional areas |
| 4a2  | Companies that use radio frequency identification technology (RFID) as part of the production and service delivery process |
| 4a3  | Companies that use two or more of the following social media: social networks, blog or micro blog of the company, websites for sharing multimedia content, and knowledge-sharing tools based on wiki |
| 4a4  | Companies that send electronic invoices corresponding to the appropriate format for automatic processing |
| 4a5  | Companies that buy medium-high satisfaction cloud computing services |
| 4b   | E-commerce                      |
| 4b1  | SMEs that sell at least 1% of total sales online |
| 4b2  | Total electronic sales by SMEs, as a percentage of their total turnover |
| 4b3  | Companies that have made electronic sales to other EU countries different to theirs |
| 5    | DIGITAL PUBLIC SERVICES         |
| 5a   | E-government                    |
| 5a1  | Individuals who use the Internet to deal with public authorities, broken down by the purpose of submitting completed forms |
| 5a2  | Amount of data that is previously filled in the online Public Services forms |
| 5a3  | Degree of completion of online services, assessment from 0 to 100 |
| 5a4  | Marking of information of the public sector |

Source: European Commission (2018) [95].

References
1. OECD. ICT for Development: Improving Policy Coherence; OECD: Paris, France, 2010.
2. Hartwick, J.M. Intergenerational equity and the investing of rents from exhaustible resources. *Am. Econ. Rev.* 1977, 66, 972–974.
3. Solow, R.M. Intergenerational equity and exhaustible resources. *Rev. Econ. Stud.* 1974, 41, 29–45. [CrossRef]
4. Solow, R.M. On the intertemporal allocation of natural resources. *Scand. J. Econ.* 1986, 88, 141–149. [CrossRef]
5. Solow, R.M. *Sustainability: An. Economist’s Perspective*; The eighteenth J. Seward Johnson Lecture; Woods Hole Oceanography Institution: Woods Hole, MA, USA, 1991.
6. Solow, R.M. An almost practical step toward sustainability. *Resour. Policy* 1993, 19, 162–172. [CrossRef]
7. Howarth, R.B.; Norgaard, R.B. Intergenerational transfers and the social discount rate. *Environ. Nat. Resour. Econ.* 1993, 3, 337–358. [CrossRef]
8. Anand, S.; Sen, A.K. Sustainable Human Development: Concepts and Priorities. *Hum. Dev. Rep. Off. Occas. Pap.* 1996, 1, 1–82.
9. Anand, S.; Sen, A.K. Human Development and Economic Sustainability. *World Dev.* 2000, 28, 2029–2049. [CrossRef]
10. Hartwick, J.M. *Pollution and National Accounting*; Institute for Economics Research, Queens University: Kingston, ON, Canada, 1990.
11. Hartwick, J.M. Natural resources, national accounting and economic depreciation. *J. Public Econ.* 1990, 43, 291–304. [CrossRef]
12. Hanley, N.; Shogren, J.; White, B. *Environmental Economics in the Theory and Practice*; Oxford University Press: New York, NY, USA, 1997.
13. United Nations. Indicators of Sustainable Development: Framework and Methodologies. Department of economics and social affairs, Commission on Sustainable Development, 2001. Available online: http://www.un.org/esa/sustdev/csd/csd9_indi_bp3.pdf (accessed on 25 July 2019).
14. Arias, F. *Desarrollo Sostenible y sus Indicadores*. Revista Sociedad y Economía 2006, 11, 200–229.
15. Vu, K.M. ICT as a source of economic growth in the information age: Empirical evidence from the 1996-2005 period. *Telecommun. Policy* 2011, 35, 357–372. [CrossRef]
16. Ho, S.C.; Kaufman, R.J.; Liang, T.P. Internet-based selling technology and e-commerce growth: A hybrid growth theory approach with cross-model inference. *Inf. Technol. Manag.* 2011, 12, 409–429. [CrossRef]
17. Warr, B.; Ayres, R.U. Useful work and information as drivers of economic growth. *Ecol. Econ.* 2012, 73, 93–102. [CrossRef]
18. Chaves, R.; Bernal, E.; Mozas, A.; Puentes, R. Improving e-economy by regional governments. *Manag. Decis.* 2014, 52, 559–572. [CrossRef]
19. Jörgenson, D.W.; Vu, K.M. The ICT revolution, world economic growth, and policy issues. *Telecommun. Policy* 2016, 40, 383–397. [CrossRef]
20. Kumar, R.R.; Stauvermann, P.J.; Samitas, A. The effects of ICT on output per worker: A study of the Chinese economy. *Telecommun. Policy* 2016, 40, 102–115. [CrossRef]
21. Venturini, F. The modern drivers of productivity. *Res. Policy* 2015, 44, 357–369. [CrossRef]
22. Solow, R. A Contribution to the Theory of Economic Growth. *Q. J. Econ.* 1956, 70, 65–94. [CrossRef]
23. Swan, T.W. Economic Growth and Capital Accumulation. *Econ. Rec.* 1956, 32, 334–361. [CrossRef]
24. Bertschek, I.; Cerquera, D.; Klein, G.J. More bits–more bucks? Measuring the impact of roadband internet on firm performance. *Inf. Econ. Policy* 2013, 25, 190–203. [CrossRef]
25. Colombo, M.G.; Croce, A.; Grilli, L. ICT services and small businesses' productivity gains: An analysis of the adoption of broadband Internet technology. *Inf. Econ. Policy* 2013, 25, 171–189. [CrossRef]
26. Haller, S.A.; Lyons, S. Broadband adoption and firm productivity: Evidence from Irish manufacturing firms. *Telecommun. Policy* 2015, 39, 1–13. [CrossRef]
27. Mayer, W.; Madden, G.; Wu, C. Broadband and economic growth: A reassessment. *Inf. Technol. Dev.* 2019, 1–18. [CrossRef]
28. Thompson, H.G.; Garbacz, C. Economic impacts of mobile versus fixed broadband. *Telecommun. Policy* 2011, 35, 999–1009. [CrossRef]
29. World Commission on Environment and Development (WCED). *Our Common Future*; Oxford University Press: Oxford, UK, 1987.
30. Constanza, R.; Patten, B.C. Defining and predicting sustainability. *Ecol. Econ.* 1995, 15, 193–196. [CrossRef]
31. Bhujabal, P.; Sethi, N. Foreign direct investment, information and communication technology, trade, and economic growth in the South Asian Association for Regional Cooperation countries: An empirical insight. *J. Public Aff.* 2019, e2010. [CrossRef]
32. Toader, E.; Firtescu, B.N.; Roman, A.; Anton, S.G. Impact of Information and Communication Technology Infrastructure on Economic Growth: An Empirical Assessment for the EU Countries. *Sustainability* 2018, 10, 3750. [CrossRef]
33. Chen, Y.; Gong, X.; Chu, C.C.; Cao, Y. Access to the Internet and Access to Finance: Theory and Evidence. *Sustainability* 2018, 10, 2534. [CrossRef]
34. Pradhan, R.P.; Mallik, G.; Bagchi, T.P. Information communication technology (ICT) infrastructure and economic growth: A causality evinced by cross-country panel data. *IIMB Manag. Rev.* 2018, 30, 91–103. [CrossRef]
35. Sepehrdoust, H. Impact of information and communication technology and financial development on economic growth of OPEC developing economies. *Kasetsart J. Soc. Sci.* 2018. [CrossRef]
36. Meijers, H. Does the Internet generate economic growth, international trade, or both? *Int. Econ. Econ. Policy* 2014, 11, 137–163. [CrossRef]
37. Kim, S. ICT and the UN’s Sustainable Development Goal for Education: Using ICT to Boost the Math Performance of Immigrant Youths in the US. *Sustainability* 2018, 10, 4584. [CrossRef]
38. Batool, R.; Sharif, A.; Islam, T.; Zaman, K.; Shoukry, A.M.; Sharkawy, M.A.; Gani, S.; Aamir, A.; Hisan, S.S. Green is clean: The role of ICT in resource management. *Environ. Sci. Pollut. Res.* 2019, 26, 25341–25358. [CrossRef] [PubMed]
39. Andreopoulos, Z.S. Green Informatics: ICT for Green and Sustainability. *Agric. Inform.* 2012, 3, 1–8. [CrossRef]
40. Hong, J; Thakuriah, P.V. Examining the relationship between different urbanization settings, smartphone use to access the Internet and trip frequencies. *J. Transp. Geogr.* 2018, 69, 11–18. [CrossRef]
41. Kostoska, O.; Kocarev, L. A Novel ICT Framework for Sustainable Development Goals. *Sustainability* 2019, 11, 161. [CrossRef]
42. Bieser, J.C.T.; Hilty, L.M. Assessing Indirect Environmental Effects of Information and Communication Technology (ICT): A Systematic Literature Review. *Sustainability* 2018, 10, 2662. [CrossRef]
43. Pohl, J.; Hilty, L.M.; Finkbeiner, M. How LCA contributes to the environmental assessment of higher order effects of ICT application: A review of different approaches. *J. Clean. Prod.* 2019, 219, 698–712. [CrossRef]
44. Schien, D.; Shabaje, P.; Yearworth, M.; Priest, C. Modeling and assessing variability in energy consumption during the use stage of online multimedia services: Energy consumption during use of online multimedia services. *J. Ind. Ecol.* 2013, 17, 800–813. [CrossRef]
45. Røpke, I.; Christensen, T.H. Transitions in the wrong direction? Digital technologies and daily life. In *Sustainable Practices Social Theory and Climate Change*; Shove, E., Spurling, N., Eds.; Routledge: Abingdon, Oxon, UK, 2013; pp. 49–68.
46. Hilty, L.M.; Aebscher, B. ICT for Sustainability: An Emerging Research Field. In *ICT Innovations for Sustainability*; Springer International Publishing: Cham, Switzerland, 2015; pp. 3–36.
47. Truby, J. Decarbonizing Bitcoin: Law and policy choices for reducing the energy consumption of Blockchain technologies and digital currencies. *Energy Res. Soc. Sci.* 2018, 44, 399–410. [CrossRef]
48. Ruth, S. Reducing ICT-related carbon emissions: An exemplar for global energy policy? *IETE Tech. Rev.* 2011, 28, 207–211. [CrossRef]
49. Moyer, J.D.; Hughes, B.B. ICTs: Do they contribute to increased carbon emissions? *Technol. Forecast. Soc. Chang.* 2012, 79, 919–931. [CrossRef]
50. Jacob, P. Information and communication technology in shaping urban low carbon development pathways. *Curr. Opin. Environ. Sustain.* 2018, 30, 133–137. [CrossRef]
51. Shabanpour, R.; Golshani, N.; Tayarani, M.; Auld, J.; Mohammadian, A. Analysis of telecommuting behavior and impacts on travel demand and the environment. *Transp. Res. Part. D Transp. Environ.* 2018, 62, 563–576. [CrossRef]
52. Giovanis, E. The relationship between teleworking, traffic and air pollution. *Atmos. Pollut. Res.* 2018, 9, 1–14. [CrossRef]
53. Asongua, S.A.; Rouxa, S.L.; Biekpeb, N. Environmental degradation, ICT and inclusive development in Sub-Saharan Africa. *Energy Policy* 2017, 111, 353–361. [CrossRef]
54. Elliot, S. Environmentally sustainable ICT: A critical topic for IS research? *PACIS 2007 Proc.* 2007, 1, 114–128.
55. Van Heddeghem, W.; Lambert, S.; Lannooy, B.; Colle, D.; Pickavet, M.; Demeester, P. Trends in worldwide ICT electricity consumption from 2007 to 2012. *Comput. Commun.* 2014, 50, 64–76. [CrossRef]
56. Houghton, J.W. ICT and the Environment in developing countries: An overview of opportunities and developments. *Commun. Strateg.* 2009, 76, 39–60.
57. Kramers, A.; Höjer, M.; Lövehagen, N.; Wangel, J. Smart sustainable cities-exploring ICT solutions for reduced energy use in cities. *Environ. Model. Softw.* 2014, 56, 52–62. [CrossRef]
58. Lee, J.W.; Brahmasrene, T. ICT, CO2 emissions and economic growth: Evidence from a panel of ASEAN. *Glob. Econ. Rev.* 2014, 43, 93–109. [CrossRef]
59. Alexandru, A.; Ianculescu, M.; Tudora, E.; Bica, O. ICT challenges and issues in climate change education. *Stud. Inform. Control* 2013, 22, 349–358. [CrossRef]
60. Jørgenson, D.W.; Ho, M.S.; Stiroh, K.J. A Retrospective Look at the U.S. Productivity Growth Resurgence. *J. Econ. Perspect.* 2008, 22, 3–24. [CrossRef]
61. Albiman, M.M.; Sulong, Z. The linear and non-linear impacts of ICT on economic growth, of disaggregate income groups within SSA region. *Telecommun. Policy* **2017**, *41*, 555–572. [CrossRef]

62. Cea, R. CSR communication in Spanish quoted firms. *Eur. Res. Manag. Bus. Econ.* **2019**, *25*, 93–98.

63. Bernal-Conesa, J.A.; Briones-Peñañalver, A.J.; De Nieves-Nieto, C. The integration of CSR management systems and their influence on the performance of technology companies. *Eur. J. Manag. Bus. Econ.* **2016**, *25*, 121–132. [CrossRef]

64. Skorupinska, A.; Torrent-Sellens, J. ICT, Innovation and Productivity: Evidence Based on Eastern European Manufacturing Companies. *J. Knowl. Econ.* **2017**, *8*, 768–788. [CrossRef]

65. Trasčă, D.L.; Ştefan, G.M.; Sahljan, D.N.; Hoinaru, R.; Serban-Oprescu, G.L. Digitalization and Business Activity. The Struggle to Catch Up in CEE Countries. *Sustainability* **2019**, *11*, 2204. [CrossRef]

66. Romer, P.M. Increasing returns and long-run growth. *J. Political Econ.* **1986**, *94*, 1002–1037. [CrossRef]

67. Romer, P.M. Endogenous Technological Change. *J. Political Econ.* **1990**, *98*, S71–S102. [CrossRef]

68. Lucas, R.E. Making a miracle. *Econometrica* **1988**, *22*, 3–42. [CrossRef]

69. Lucas, R.E. On the Mechanics of Economic Development. *J. Political Econ.* **1993**, *101*, S94–S105. [CrossRef]

70. Rigdon, E.E.; Sarstedt, M.; Ringle, C.M. On comparing results from CB-SEM and PLS-SEM: Five perspectives and five recommendations. *Mark. Zfp* **2017**, *39*, 4–16. [CrossRef]

71. Hair, J.F.; Hult, G.T.M.; Ringle, C.M.; Thiele, K.O. Mirror, mirror on the wall: A comparative evaluation of composite-based structural equation modeling methods. *J. Acad. Mark. Sci.* **2017**, *45*, 616–632. [CrossRef]

72. Gefen, D.; Straub, D.W.; Rigdon, E.E. An update and extension to SEM guidelines for administrative and social science research. *Manag. Inf. Syst. Q.* **2011**, *35*, 3–24. [CrossRef]

73. Rigdon, E.E. Partial least squares path modeling. In *Structural Equation Modeling: A Second Course*, 2nd ed.; Hancock, G.R., Mueller, R.O., Eds.; Information Age: Charlotte, NC, USA, 2013; pp. 81–116.

74. Richter, N.F.; Cepeda-Carrion, G.; Roldán Salgueiro, J.L.; Ringle, C.M. European management research using partial least squares structural equation modeling (PLS-SEM). *Eur. Manag. J.* **2016**, *34*, 589–597. [CrossRef]

75. Hair, J.F.; Hult, G.T.M.; Ringle, C.M.; Sarstedt, M.; Thiele, K.O. Mirror, mirror on the wall: A comparative evaluation of composite-based structural equation modeling methods. *Mark. Zfp* **2017**, *39*, 4–16. [CrossRef]

76. Nitzl, C.; Chin, W.W. The case of partial least squares (PLS) path modeling in managerial accounting research. *J. Manag. Control* **2017**, *28*, 137–156. [CrossRef]

77. Henseler, J.; Ringle, C.M.; Sarstedt, M. A new criterion for assessing discriminant validity in variance-based structural equation modeling. *J. Acad. Mark. Sci.* **2015**, *43*, 115–135. [CrossRef]

78. Licerá-Gutiérrez, A.; Cano-Rodriguez, M. Using partial least squares in archival accounting research: An application to earnings quality measuring. *Span. J. Financ. Account./Revista Española de Financiación y Contabilidad* **2019**, *1*, 1–28. [CrossRef]

79. Sarstedt, M.; Ringle, C.M.; Hair, J.F. Partial Least Squares Structural Equation Modeling. In *Handbook of Market Research*; Springer International Publishing: Cham, Vietnam, 2017; Volume 26, pp. 1–40. [CrossRef]

80. Shmueli, G.; Ray, S.; Estrada, J.M.V.; Chatla, S.B. The elephant in the room: Predictive performance of PLS models. *J. Bus. Res.* **2016**, *69*, 4552–4564. [CrossRef]

81. Barroso, C.; Cepeda, G.; Roldán, J.L. Applying Maximum Likelihood and PLS on Different Sample Sizes: Studies on SERVQUAL Model and Employee Behavior Model. In *Handbook of Partial Least Squares; Vinzi, V.E., Chin, W., Henseler, J., Wang, H., Eds.; Springer Handbooks of Computational Statistics; Springer: Berlin/Heidelberg, Germany, 2010;* pp. 427–447.

82. Céspedes, J.; Sánchez, M. Tendencias y desarrollo recientes en métodos de investigación y análisis de datos en dirección de empresas. *Revista Europea de Dirección y Economía de la Empresa* **1996**, *5*, 23–40.

83. Chin, W.W. The partial least squares approach to structural equation modeling. In *Modern Methods for Business Research*; Marcoulides, G.A., Ed.; Erlbaum: Mahwah, NJ, USA, 1998.

84. Hair, J.F.; Ringle, C.M.; Sarstedt, M. PLS-SEM: Indeed a silver bullet. *J. Mark. Theory Pract.* **2011**, *19*, 139–152. [CrossRef]

85. Hair, J.F.; Sarstedt, M.; Hopkins, L.; Kuppelwieser, V.G. Partial least squares structural equation modeling (PLS-SEM) An emerging tool in business research. *Eur. Bus. Rev.* **2014**, *26*, 106–121. [CrossRef]

86. Nunnally, J.C. *Psychological Theory*; MacGraw-Hill: New York, NY, USA, 1994.

87. Dijkstra, T.K.; Henseler, J. Consistent partial least squares path modeling. *MIS Q.* **2015**, *39*, 2. [CrossRef]
88. Bagozzi, R.P.; Yi, Y. On the evaluation of structural equation models. *J. Acad. Mark. Sci.* 1988, 16, 74–94. [CrossRef]

89. Fornell, C.; Larcker, D. Structural equation models with unobservable variables and measurement error: Algebra and Statistics. *J. Mark. Res.* 1981, 18, 39–50. [CrossRef]

90. Henseler, J.; Ringle, C.M.; Sinkovics, R.R. The use of partial least squares path modeling in international marketing. In *New Challenges to International Marketing*; Emerald Group Publishing Limited: Bingley, UK, 2009; pp. 277–319.

91. Fernández, A. Factores determinantes para la elaboración de un modelo de éxito de la empresa en el medio digital. Diss. tesis doctoral, Departamento de Economía Financiera y Contabilidad, Universidad de Extremadura, Badajoz, Spain, 2016.

92. Fernández-Portillo, A.; Hernández-Mogollón, R.; Sánchez-Escobedo, M.C.; Coca-Pérez, J.L. Does the Performance of the Company Improve with the Digitalization and the Innovation? In *Annual Meeting of the European Academy of Management and Business Economics*; Springer: Cham, Switzerland, 2018; pp. 276–291.

93. Robina-Ramírez, R.; Fernández-Portillo, A.; Díaz-Casero, J.C. Green Start-Ups’ Attitudes towards Nature When Complying with the Corporate Law. *Complexity* 2019, 4164853.

94. Hair, J.F.; Risher, J.J.; Sarstedt, M.; Ringle, C.M. When to use and how to report the results of PLS-SEM. *Eur. Bus. Rev.* 2019, 31, 2–24. [CrossRef]

95. European Comision. The Digital Economy and Society Index. Available online: https://ec.europa.eu/digital-single-market/en/desi (accessed on 5 May 2019).

© 2019 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (http://creativecommons.org/licenses/by/4.0/).