WILL INFORMATION AND COMMUNICATION TECHNOLOGY DEVELOPMENTS KEEP UP WITH THE GLOBAL GOALS OF REDUCING CARBON EMISSIONS?

INTRODUCTION

Climate change has pushed the world into coming up with alternatives to the way that societies are organized. Changes in lifestyles, production systems, water, energy and food consumption, to mention a few, are required if we want the average increase in global temperature to remain below 2°C (Peters et al. 2013; United Nations [UN] 2015; 2020; Williams, Heucher and Whiteman 2021). Scholars of all disciplines, the information systems (IS) field included, have been discussing such alternatives and proposing solutions. Most have argued that information and communication technologies (ICTs) play a key role in helping tackle the challenges involved in such necessary and urgent changes (Watson et al., 2021).

Indeed, there is empirical evidence that ICTs help to reduce carbon emissions (Chen et al., 2019; Ulucak et al., 2020). However, it is also true that ICTs contribute to carbon emissions throughout their lifecycle (Hilty & Bieser, 2017; Park et al., 2018). These two-way impacts lead to what is called the ICT paradox (Qureshi, 2019). Therefore, scholars currently investigate the balance between these impacts and studies suggest that there is a threshold level in the carbon emission curve where ICTs stop contributing to pollution and start contributing to reducing it, which occurs after a country achieves a mature, developed country-like state of ICT infrastructure and economy (Higón et al., 2017).

Such a phenomenon is known as the inverted U-shaped relationship between ICTs and carbon dioxide (CO_2) emissions and is founded on the environmental Kuznets curve (EKC). The evidence of this relationship has been reported in several studies (Boubellouta & Kusch-Brandt, 2020; Higón et al., 2017; Shahnazi & Shabani, 2019; Ulucak et al., 2020). What also has an inverted U-shape curve, however, is the current global goal of reducing the total CO_2 emissions by 76% by 2030 before global warming reaches a point where no mitigation measures will produce significant effects anymore (Friedlingstein et al., 2011; UN, 2019, 2020).

This restriction poses challenges to ICT developments. On the one hand, ICT artifacts should continue to spread because of their potential to promote individuals, societies, and economies. On the other hand, efforts must be put to substantially diminish their CO_2 emissions, currently estimated to be about 3–3.6% of the global carbon emissions (Belkhir & Elmeligi, 2018). Given that one curve has a strict deadline whereas the other has only conceptual definitions that are highly dependent on investments, government actions and public policies, in addition to having no deadline, we raise the following question: can the inverted U-shaped relationship between ICTs and CO_2 emissions keep up with the current global goal of reducing carbon emissions?

To answer this question, this research project will use panel data from the Organisation for Economic Co-operation and Development (OECD, 2020) to estimate mathematical models and compare both curves to investigate whether the current pace of ICT developments worldwide keep up with, forge ahead of, or lag behind, the UN's goal. If the latter is the case, this project will then estimate how much should the pace increase so that countries reach the threshold level more quickly. In achieving this objective, the results will offer valuable contributions to the understanding of the EKC dynamics in the ICT field, in addition to having practical implications for industries designing sustainable ICTs and for governments promulgating regulations, promoting economic growth and designing public policies.

GLOBAL WARMING, CLIMATE CHANGE AND THE UN'S GLOBAL GOALS

Global warming is caused by increased levels of pollutants in the atmosphere, namely greenhouse gases (GHG). In his controversial book, Lovelock (2010) says that the evidence of global warming is threefold: (i) the sea-level rise (Rahmstorf, 2007), because water expands on heating; (ii) the melting of Arctic ice, which had its area reduced by 60% in less than three decades; and (iii) the decline of marine algae population caused by the increase in the barren area of the ocean (Polovina et al., 2008).

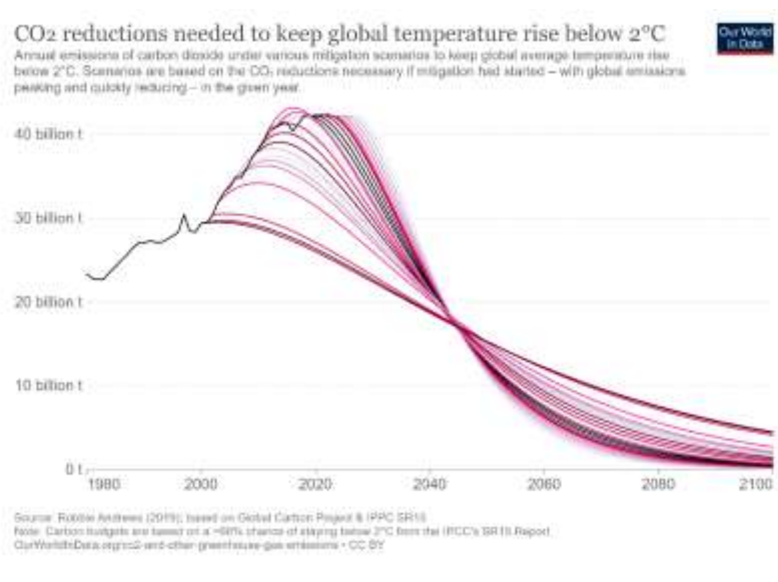
Since the discovery of the Ozone hole in the 1980s caused by the emissions of chlorofluorocarbons (CFCs), the international community has debated the human impacts on the environment and presented several proposals to mitigate those impacts. The initiatives led to many International Environmental Agreements known as the UNFCCC (Framework Convention on Climate Change), such as the conference held in Rio de Janeiro in 1992, the Kyoto Protocol set in 1997 and the Paris Agreement reached in 2015 and signed by 197 countries (European Commission [EC], 2021).

The Intergovernmental Panel on Climate Change (IPCC) has been the main body responsible for reporting scientific information on climate change. Without losing sight of the fact that their climate estimates are considered by the scientific community to be very conservative, IPCC claims that, in order to avoid serious consequences of global warming, global temperature rise must be kept below 2°C throughout this century (UN, 2015, 2020) and the most important way of doing so is by reducing carbon emissions.

Fig. 1 shows the limits of CO_2 emissions needed to keep global temperature rise below 2°C. The turning point must be reached in this decade, which makes the decade decisive for achieving the goal, considering a >66% chance of falling below 2°C (Knutti & Hegerl, 2008). Ironically, ten years ago Friedlingstein et al. (2011) estimated that, if mitigations started at that time, considerable efforts would be necessary to reduce CO_2 emissions by 5% p.a. History shows that, four years later, what occurred was that the mitigation rate had to be readjusted to the current 7.6% p.a.

Figure 1

CO_2 reductions needed to keep global temperature rise below 2°C



Source: Our World in Data (OWID, 2021).

Carbon emissions are also associated with economic growth (Grossman & Krueger, 1995). Hence, not only countries will need to cut carbon emissions to keep the Earth system stable (Steffen et al., 2015) but they will also need to look for alternative and sustainable energy sources to support their growth. This poses greater challenges mainly to low economies, which do not have the same resources and conditions that developed economies do. That is why the UN and the Paris Agreement also bring to the discussion the inequality of carbon emissions per capita. According to the latest UN's Emissions Gap Report (UN, 2020), the richest countries in the world (which represents only 1% of the total) need to reduce their current emissions thirtyfold or so by 2030 while the poorest 50% can rather increase their current levels threefold during the same period.

This means that there is still room for developing countries to grow and develop in all spheres of economy, production and society, provided that the goal of reducing global carbon emissions be kept on track and the turning point be reached by 2030. Among those developments, it is of particular interest to this research project the ICT development field, given the aforementioned relevance that ICTs have to all spheres.

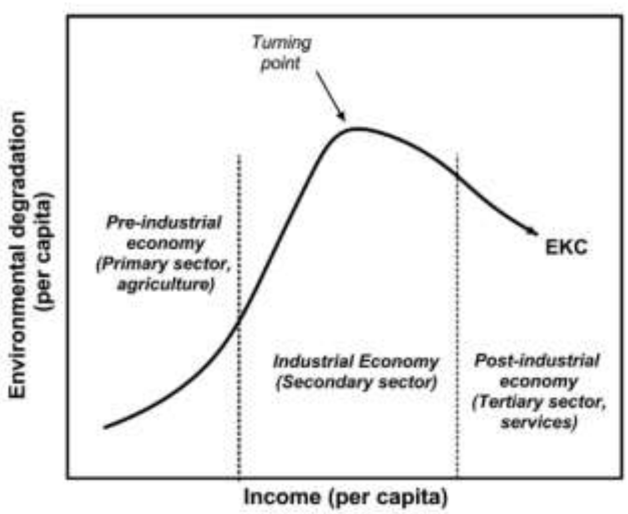
THE EKC THEORY IN THE ICT CONTEXT

Although conceived in 1955 by Simon Kuznets, the EKC theory became popular in the 1990s from the discussion of the negative effects of economic growth on the environment. From that onward, economic discussions changed from 'the exhaustion of natural resources and environmental degradation to issues concerning the necessity of economic growth to overcome environmental deterioration and pollution' (Kaika & Zervas, 2013, p. 1392).

The reasoning behind the EKC theory is that accelerating economic growth will achieve higher world output and better ways of protecting the environment (Ekins, 1993; Kaika & Zervas, 2013). In other words, some damage to the environment is necessary before achieving sustainable growth. Therefore, according to this theory, at some point in time environmental degradation will stop increasing and start decreasing due to advancements in technology and income. When plotting this progression on a chart, one obtains the inverted U-shape curve depicted in Fig. 2.

Figure 2

An environmental Kuznets curve

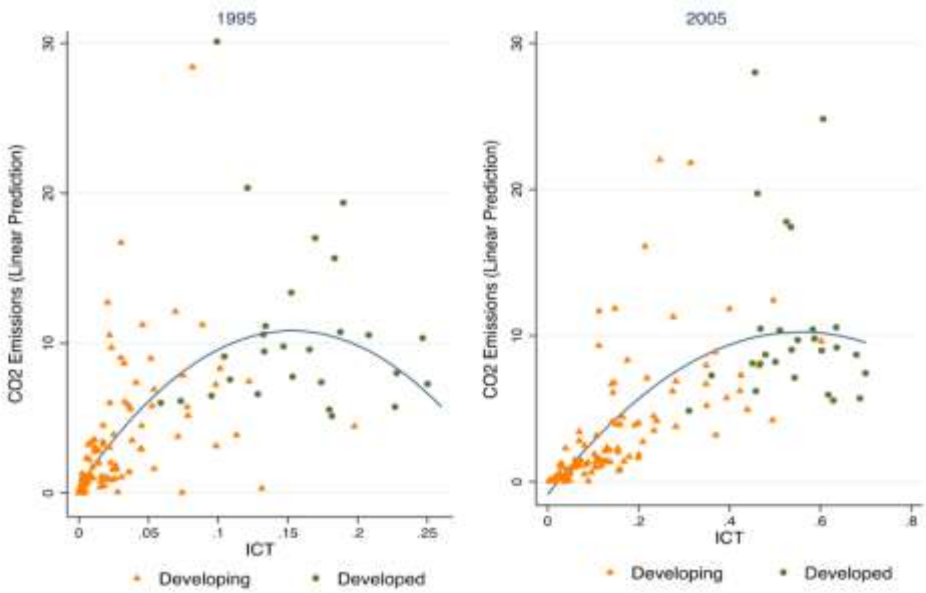


Source: Kaika and Zervas (2013, p. 1394).

The EKC hypothesis has been tested in varied studies, such as oil exploitation (Esmaeili & Abdollahzadeh, 2009), income inequality (Grunewald et al., 2017), electricity production and consumption (Jiang et al., 2021), economic complexity (Pata, 2021), e-waste (Boubellouta & Kusch-Brandt, 2020) and ICT development (Ulucak et al., 2020). In the IS field, the inverted U-shaped relationship between ICT and CO_2 emissions has been widely confirmed. In Fig. 3 we see Higón, Gholami and Shirazi's (2017) prediction of the ICT's EKC. The *x*-axis represents the ICT index, which consists of the combination of two stages of ICT development: ICT readiness and ICT use and intensity.

Figure 3

CO_2 emissions and ICT in developing and developed countries



Note. The *x*-axis represents the ICT Index and was constructed by combining: (i) the number of fixed telephone subscribers per 100 inhabitants lines, (ii) mobile cell phone subscribers per 100 inhabitants, (iii) PC owners per 100 inhabitants, (iv) percentage of individuals using internet and (v) fixed-broadband subscribers per 100 inhabitants. Source: Higón, Gholami and Shirazi (2017, p. 90).

Research on the ICT's CO_2 emissions has been advancing in the last decade. Studies have been carried out from both regional and global perspectives (Shahnazi & Shabani, 2019; Ulucak et al., 2020). Besides, scholars of the EKC theory argue about the importance of covariates in the estimation models to assure robustness (Torras & Boyce, 1998) and this call has received attention as well (Higón et al., 2017). Additionally, Belkhir and Elmeligi (2018) warn us that the composition of what can be understood as ICT artifacts and ITC-related pollutants is equally important because, otherwise, conclusions can be misleading. For example, the authors claim that the carbon emissions of smartphones have been nearly completely neglected in the literature even though they comprise 11% of the total ICT contribution to GHG emissions, which the authors estimate to be around 2,000 million tonnes of carbon dioxide equivalent (Mt-CO_2-eq). Lastly, studies also suggest that the EKC hypothesis does not apply to Internet use (Park et al., 2018), at least in the European Union (EU) context. Despite the limitations and inconsistences, by and large the conclusions are that ICT does play a key role in countries' development and pays off its environmental degradation as time goes by.

It is, therefore, widely confirmed in the ICT-EKC literature that countries achieve a turning point in carbon emissions after they become developed, which Higón, Gholami and Shirazi (2017) predicted to be at an ICT development index of about 0.30. However, despite the large number of studies investigating the EKC between ICT and CO_2 emissions, the concern with a deadline for reaching the turning point has not been emphasized. We of course acknowledge that setting a deadline for ICT development is not simple because many countries, especially the least developed ones, face several difficulties of all matters, such as low human development index (HDI), social inequalities, violence, poor infrastructure and political issues. These restrictions not only severely prevent them from focusing on one dimension or another but also force them to fight on many fronts simultaneously.

Nevertheless, this does not change the fact that a race against time is ongoing and a bold goal needs to be achieved. Therefore, beyond estimating the relationship between ICT and carbon emission, it is necessary to estimate what pace each country is at and how long it will take for a given country to reach the turning point considering its pace.

The hypothesis here is that not all countries can meet the global carbon emission reduction deadline and, as far as we can tell, this hypothesis has not been tested yet. One way of testing it could be by comparing the curves shown in Fig. 1 and 3. At first, because the horizontal axes of the figures are not on the same scale, comparisons cannot be made. However, this can be overcome by converting the ICT index into an annual rate of progress and by estimating such an annual rate with historical data, for example, the OECD's or World Bank's. That is precisely what this project aims for.

FINAL CONSIDERATIONS

This research-in-progress paper is in its initial stages. Hitherto, our review of the literature has found no scientific work addressing countries' ICT development pace relative to the UN's Global Goals. Given that even the most conservative climate projections refer to this decade as the one that will determine whether global temperature rise will or will not be kept below 2°C throughout the 21st century, it is fundamental to keep track of countries' ICT development status because the clock is ticking and the world is running out of time. As of September 2021, when this project is being written, mankind has less than ten years to meet the UN's goals. In such an unequal world like this one, where not even global pollution is equally distributed, developing economies should, responsively, take more advantage of their limits to thrive properly and at a high pace without losing sight of the Global Goals. Few would disagree with that indeed. However, the question posed in the title of this paper remains: will ICT developments keep up with the Global Goals of reducing carbon emissions?

REFERENCES

Belkhir, L., & Elmeligi, A. (2018). Assessing ICT global emissions footprint: Trends to 2040 & recommendations. *Journal of Cleaner Production*, *177*, 448–463. https://doi.org/10.1016/j.jclepro.2017.12.239

Boubellouta, B., & Kusch-Brandt, S. (2020). Testing the environmental Kuznets Curve hypothesis for E-waste in the EU28+2 countries. *Journal of Cleaner Production, 277.* https://doi.org/10.1016/j.jclepro.2020.123371

Chen, X., Gong, X., Li, D., & Zhang, J. (2019). Can information and communication technology reduce CO_2 emission? A quantile regression analysis. *Environmental Science and Pollution*

Research, *26*(32), 32977–32992. https://doi.org/10.1007/s11356-019-06380-8

EC. (2021). *Environment: International Issues*. https://ec.europa.eu/environment/international_issues/agreements_en.htm

Ekins, P. (1993). “Limits to growth” and “sustainable development”: grappling with ecological realities. *Ecological Economics*, *8*, 269–288.

Esmaeili, A., & Abdollahzadeh, N. (2009). Oil exploitation and the environmental Kuznets curve. *Energy Policy*, *37*(1), 371–374. https://doi.org/10.1016/j.enpol.2008.08.022

Friedlingstein, P., Solomon, S., Plattner, G. K., Knutti, R., Ciais, P., & Raupach, M. R. (2011). Long-term climate implications of twenty-first century options for carbon dioxide emission mitigation. *Nature Climate Change*, *1*(9), 457–461. https://doi.org/10.1038/nclimate1302

Grossman, G. M., & Krueger, A. B. (1995). Economic Growth and the Environment. *The Quarterly Journal of Economics*, *110*(2), 353–377.

Grunewald, N., Klasen, S., Martínez-Zarzoso, I., & Muris, C. (2017). The Trade-off Between Income Inequality and Carbon Dioxide Emissions. *Ecological Economics*, *142*, 249–256. https://doi.org/10.1016/j.ecolecon.2017.06.034

Higón, D. A., Gholami, R., & Shirazi, F. (2017). ICT and environmental sustainability: A global perspective. *Telematics and Informatics*, *34*(4), 85–95. https://doi.org/10.1016/j.tele.2017.01.001

Hilty, L., & Bieser, J. (2017). Opportunities and Risks of Digitalization for Climate Protection in Switzerland. *Zurich Open Repository and Archive*, *January*, 1–62. https://doi.org/10.5167/uzh-141128

Jiang, Q., Khattak, S. I., & Rahman, Z. U. (2021). Measuring the simultaneous effects of electricity consumption and production on carbon dioxide emissions (CO2e) in China: New evidence from an EKC-based assessment. *Energy*, *229*. https://doi.org/10.1016/j.energy.2021.120616

Kaika, D., & Zervas, E. (2013). The Environmental Kuznets Curve (EKC) theory-Part A: Concept, causes and the CO2 emissions case. *Energy Policy*, *62*, 1392–1402. https://doi.org/10.1016/j.enpol.2013.07.131

Knutti, R., & Hegerl, G. C. (2008). The equilibrium sensitivity of the Earth’s temperature to radiation changes. In *Nature Geoscience* (Vol. 1, Issue 11, pp. 735–743). https://doi.org/10.1038/ngeo337

Kuznets, S. (1955). Economic Growth and Income Inequality. *The American Economic Review*, *45*(1), 1–28.

Lovelock, J. (2010). *The Vanishing Face of Gaia: A Final Warning*. Basic Books.

OECD. (2020). *OECD data: search results*. OECD. https://data.oecd.org/searchresults/?hf=20&b=0&r=%2Bf%2Ftype%2Fdatasets&r=%2Bf%2Ftopics_en%2Fenvironment&l=en&s=score

OWID. (2021). *CO_2 reductions needed to keep global temperature rise below 2°C*. Our Word in Data. https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions

Park, Y., Meng, F., & Baloch, M. A. (2018). The effect of ICT, financial development, growth, and trade openness on CO2 emissions: an empirical analysis. *Environmental Science and Pollution Research*, *25*(30), 30708–30719. https://doi.org/10.1007/s11356-018-3108-6

Pata, U. K. (2021). Renewable and non-renewable energy consumption, economic complexity, CO2 emissions, and ecological footprint in the USA: testing the EKC hypothesis with a structural break. *Environmental Science and Pollution Research*, *28*(1), 846–861. https://doi.org/10.1007/s11356-020-10446-3

Peters, G. P., Andrew, R. M., Boden, T., Canadell, J. G., Ciais, P., Le Quere, C., Marland, G., Raupach, M. R., & Wilson, C. (2013). The challenge to keep global warming below 2 degrees C. *Nature Climate Change*, *3*(1), 4–6.

Polovina, J. J., Howell, E. A., & Abecassis, M. (2008). Ocean's least productive waters are expanding. *Geophysical Research Letters*, *35*(3), L03618. https://doi.org/10.1029/2007GL031745

Qureshi, S. (2019). Climate change adaptation for sustainable development: the information and communication technology (ICT) paradox. *Information Technology for Development*, *25*(4), 625–629. https://doi.org/10.1080/02681102.2019.1680164

Rahmstorf, S. (2007). A semi-empirical approach to projecting future sea-level rise. *Science*, *315*(5810), 368–370. https://doi.org/10.1126/science.1135456

Shahnazi, R., & Shabani, Z. D. (2019). The effects of spatial spillover information and communications technology on carbon dioxide emissions in Iran. *Environmental Science and Pollution Research*, *26*(23), 24198–24212. https://doi.org/10.1007/s11356-019-05636-7

Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., Biggs, R., Carpenter, S. R., De Vries, W., De Wit, C. A., Folke, C., Gerten, D., Heinke, J., Mace, G. M., Persson, L. M., Ramanathan, V., Reyers, B., & Sörlin, S. (2015). Planetary boundaries: Guiding human development on a changing planet. *Science*, *347*(6223). https://doi.org/10.1126/science.1259855

Torras, M., & Boyce, J. K. (1998). Income, inequality, and pollution: A reassessment of the environmental Kuznets curve. *Ecological Economics*, *25*(2), 147–160. https://doi.org/10.1016/S0921-8009(97)00177-8

Ulucak, R., Danish, & Khan, S. U. D. (2020). Does information and communication technology affect CO_2 mitigation under the pathway of sustainable development during the mode of globalization? *Sustainable Development*, *28*(4), 857–867. https://doi.org/10.1002/sd.2041

UN. (2015). *Take Action for the Sustainable Development Goals*. United Nations. https://www.un.org/sustainabledevelopment/sustainable-development-goals/

UN. (2019). *Emissions Gap Report 2019: Global progress report on climate action*. UNEP. https://www.unep.org/interactive/emissions-gap-report/2019/

UN. (2020). *Emissions Gap Report 2020*. United Nations Environment Programme (UNEP).

Watson, R. T., Elliot, S., Corbett, J., Farkas, D., Feizabadi, A., Gupta, A., Iyer, L., Sen, S., Sharda, R., Shin, N., Thapa, D., & Webster, J. (2021). How the AIS can Improve its Contributions to the UN's Sustainability Development Goals: Towards A Framework for Scaling Collaborations and Evaluating Impact. *Communications of the Association for Information Systems*, *48*(1), 476–502. https://doi.org/10.17705/1CAIS.04841

Williams, A., Heucher, K., & Whiteman, G. (2021). Planetary Emergency and Paradox. In R. Bednarek, M. P. Cunha, J. Schad, & W. . Smith (Eds.), *Interdisciplinary Dialogues on Organizational Paradox: Learning from Belief and Science, Part A (Research in the Sociology of Organizations, Vol. 73a)* (pp. 151–170). Emerald Publishing Limited. https://doi.org/10.1108/S0733-558X2021000073a012