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ICT and environmental sustainability: A global perspective

Dolores Añón Higón [a,*], Roya Gholami [b], Farid Shirazi [c]

[a] Facultad de Economía and ERI-CES, Universitat de València, Valencia, Spain
[b] Department of Management Information Systems, University of Illinois, Springfield, United States
[c] Ted Rogers School of Information Technology Management, Ryerson University, Toronto, Canada

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ABSTRACT

The positive and negative environmental impacts of information and communication technologies (ICTs) are widely debated. In theory, ICT is among the sources contributing to the increasing levels of CO_2 emissions in terms of production of ICT machinery and devices, energy consumption, and recycling of electronic waste. However, ICT is also expected to reduce CO_2 emissions on a global scale by developing smarter cities, transportation systems, electrical grids, industrial processes, and energy saving gains. These two effects work in opposite direction, creating an inverted-U relationship between ICT and CO_2 emissions. The aim of this study is to investigate this non-linear relationship between ICT and CO_2 emissions on a global scale. Given that global warming is a global issue, it is necessary to look at this relationship in countries at all levels of development. To this end, we use a panel data set consisting of 142 economies, split into 116 developing and 26 developed countries, over the period 1995–2010. The results of our empirical study confirm that the relationship between ICT and CO_2 emissions is an inverted U-shaped relationship. Moreover, while for the sample of developing countries, the ICT turning point is well above the mean value, the opposite is true for the sample of developed countries. This implies that many developed countries have already attained the level of ICT development, at which CO_2 emissions decreases as the level of ICT development improves further.

1. Introduction

ICT can have both negative and positive impacts on the environment. ICT production, use, and disposal have negative environmental impacts, and increase CO_2 emissions resulting from electricity production. According to Røpkea and Christensen (2012) the use of ICT have direct impacts on electricity consumption, it also gives rise to energy consumption in relation to the production of equipment and the running of the infrastructure, such as server parks and datacenters. The ICT sector has been estimated to produce 2% of global greenhouse gas emissions (GHG) (Mingay, 2007). Therefore, making the production, use and disposal of ICT greener refers to '*green ICT*'. The green ICT view sees ICT primarily as a problem to be mitigated (Dedrick, 2010; Molla et al., 2009). On the other hand, ICT can reduce emissions by building smarter cities, transportation systems, electrical grids and industrial processes. The '*ICT for green*' view sees ICT as a possible solution to many environmental problems. There is much hope that ICT can be a major part of the solution in dealing with climate change and related environmental challenges (European e-Business Report, 2010; Elliot, 2011; Melville, 2010; Watson et al., 2012; Gholami et al., 2013).

* Corresponding author at: Facultad de Economía and ERI-CES, Universitat de València, Avda. de los Naranjos S/N, 46022, Valencia, Spain.
E-mail addresses: m.dolores.anon@uv.es (D. Añón Higón), rghol2@uis.edu (R. Gholami), f2shiraz@ryerson.ca (F. Shirazi).

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The Global e-Sustainability Initiative report (GeSI, 2008) known as SMART 2020 report claims that ICT will increase to an estimated 2.8% of total global CO_2 emissions by 2020 but ICT can reduce CO_2 emissions by 15% of predicted total global CO_2 emissions (GeSI, 2008). The biggest opportunities for ICT are in smart motor systems, logistics, buildings, grids and dematerialization (GeSI, 2008). It is important to understand the net impact of ICT on environment. However, the empirical evidence on how ICT contributes to environmental sustainability particularly at macroeconomic and global level is scarce.

Before the recent call for wider research on the impact of ICT on environmental sustainability (e.g. Elliot, 2011; Melville, 2010; Watson et al., 2012; Melville and Whisnant, 2014), there was limited research applying information systems (IS) perspective in this area (Heng and de Moor, 2003). While there are regional studies on the potential of IT for reducing CO_2 emissions, however, the previous literature does not provide comparable empirical evidence (Dedrick, 2010; Melville, 2010) on a global scale. European E-Business Report (2010) investigates the relationship between ICT and CO_2 emissions for a sample of EU countries and finds that ICT significantly decreases CO_2 emissions per output in the '*energy supply sector*'. Lee and Brahmasrene (2014) examine the relationships among ICT, CO_2 emissions and economic growth for a panel of nine countries from the Association of Southeast Asian Nations (ASEAN) for the period 1991–2009. They find that ICT has significant positive impact on both economic growth and CO_2 emissions. The findings also suggest an inverse bidirectional relationship between economic growth and CO_2 emissions.

Other scholars argue that the net impact of ICT on environment is theoretically ambiguous and worth empirical analysis (Melville, 2010; Dedrick, 2010). To our knowledge, the positive and negative impacts of ICT on CO_2 emissions have not yet been comprehensively investigated on a '*global*' scale. Given the global characteristics of environmental issues, it is necessary to look at this relationship in countries at all levels of development. Only then can effective steps be taken by companies, governments, individuals and international organizations to reduce negative and increase positive impacts. Building a model that incorporates economic development, ICT and other factors is an important step in this direction as well as the collection of a large and diverse set of data to test the model.

Thus, the research questions this article will investigate are, (i) *What impact ICT has on CO_2 emissions in general?* and (ii) *Does the extent of this impact depend on the level of economic development?* A macroeconomic approach examining the relationship between ICT, economic development and CO_2 emissions may help us answer these questions. We apply a panel-based approach which allows us to test the robustness of the relationship between ICT and CO_2 emissions, not only for the globe as a whole but also for a sample of developed and developing countries. To do so, we introduce non-linearities in the relationship between ICT and CO_2 emissions at global scale.

The paper proceeds as follows. Section 2 outlines the theoretical background whereby the model and main hypothesis are developed. In Section 3, the model is presented. The data are discussed in Section 4, while the empirical results are presented in Section 5. The paper concludes with strengths and limitations of the research.

2. Theoretical background

The most relevant literature in this area is the literature from the *Production Theory*. The Nobel laureate economist Robert Solow once cited the infamous *productivity paradox* of the US economy, where productivity stagnated despite increasing computing power. An extensive body of literature shows that we have long moved past the early debate on productivity paradox (Barua et al., 2010). ICT contribution to productivity and economic growth is now widely accepted. Recent research, the so called '*ICT value*' literature, establishes that ICT's value creation occurs under certain conditions and that value manifests itself in many ways (Kohli and Grover, 2008; Gholami and Kohli, 2014; Lee et al., 2005).

2.1. ICT and economic growth: the production theory

Majority of the previous papers in '*ICT value*' literature at country level have found that ICT investment has a positive and significant impact on *productivity* for developed countries but not for developing countries (Ollo-Lopez and Aramendía-Muneta, 2012; Pohjola, 2001; Dewan and Kraemer, 2000; Schreyer, 2000). However, developing countries have continued investing in their ICT infrastructure and it is essential now to investigate whether the ICT investment has begun to pay off in developing countries as well (Dedrick et al., 2013). Dedrick et al. (2013) investigate this question using data for 45 countries for the period 1994–2007, and compare the results with the period 1985–1993 (Dewan and Kraemer, 2000). They find that upper-income developing countries have achieved positive and significant productivity gains from ICT investment in the more recent period. They also find that the productivity effects of ICT are moderated by country factors such as human resources and openness to foreign investment.

ICT not only improves productivity (Ollo-Lopez and Aramendía-Muneta, 2012), it can also reduce emissions by building smarter cities, transportation systems, electrical grids and industrial processes. ICT can improve carbon productivity as input to production systems and by optimizing production processes (Dedrick, 2010). Watson et al. (2010) discuss the transformative ability of ICT in order to create an environmentally sustainable society. The extant research highlights the need for broadening the scope of the ICT value research beyond the established financial and economic frameworks. The ICT value literature contains over 200 publications examining the impact of ICT on firm or country level performance mainly from an '*economic*' perspective. Addition of '*environmental*' value is a natural extension to the ICT value literature (Melville,