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The Effects of *Information and Communications Technology* (ICT) on air pollution

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ABSTRACT

The relationship between ICT and the environment has a key role in today's environmental discussions. This paper evaluates and analyses how "ICT" initiatives and applications, can play a major role in reducing CO2 emissions, and ensuring sustainable development and green growth in order to meet development goals and improve quality of life in some developed and developing countries by using dynamic panel estimation by Generalized Method of Moments (GMM) with 43 economies for the period from 2003 to 2008 .The results indicate that despite the positive effect of the economic growth on the environmental pollution, ICT advances, ,has played an important role in the reduction of carbon dioxide as air pollutant.

Introduction

The impact of human activities on the environment – and on climate change in particular – are issues of growing concern confronting life on Earth.It is hard to argue that the global eco-system is not under pressure due to climate change-related effects which are linked to greenhouse gas (GHG) emissions. Scientists have been debating how much GHG the world could emit in total and have warned that the world is on course for disaster. Even the most drastic emissions cuts currently being discussed stand little chance of limiting global warming to safe levels; two recent studies published in Nature by scientists in England and Germany have found prompting calls for radical rethinking on how to tackle climate change. These studies predict that if present emissions and trends continue, an estimated trillion tones of carbon dioxide will be emitted by the year 2050 which is enough to push the planet into a danger zone which could lead to catastrophic consequence.[1] Nature (2009))

In the face of these challenges and crises, ICT can play a major role in reducing the emissions of carbon dioxide and other GHGs, directly and indirectly through reduction in energy consumption and material inputs, while accelerating socio-economic development which is required by developing countries more than ever. The direct impacts of ICT on climate change – both negative and positive - are increasingly being recognized. ICT can increase efficiency in various socio-economic activities. Although ICTs require energy resources, they also offer a number of opportunities to advance global environmental research, planning and action. This includes monitoring and protecting the environment as well as mitigation of and adaptation to climate change.

Information and communication technologies (ICTs) are being rapidly deployed around the world.In the past 10 years or so, the availability and use of ICTs has grown dramatically around the world. (Malmodin 2009)In the developing world especially, this growth has been largely due to the growth of mobile telephony.While the penetration of ICTs in the developed world has reached high levels, the penetration of ICTs in the developing world is still growing and there are marked differences between different categories of countries.

ITU data[2] shows :

- That countries of the Organisation for Economic Co-operation and Development (OECD) augmented by Taiwan, China; Hong Kong, Macao, and Singapore ("OECD +"), accounting for 18.7 per cent of the world's population, have demonstrated marked growth in ICT uptake with the exception of fixed line access.
- Whereas in the least developed countries (LDCs) which are made up of the "...50 least developed countries, recognized by the United Nations as requiring special attention in development assistance, accounting for 11.9 per cent of the world's population", growth rates are very low.
- In all other countries, which are termed developing and which account for 69.7 per cent of the world's population, rates are growing but albeit not at the same rapid pace as the developed countries in the "OECD +" categorization.

Using the green growth premise of inter-linked social, economic, and environmental systems, this paper evaluates and analyses how "ICT" initiatives and applications, can play a major role in reducing CO2 emissions, and ensuring sustainable development and green growth in order to meet development goals and improve quality of life in developed and developing countries.

At the same time, it should be noted that literature pertaining to ICT and their relationship to harmful emissions is

[1] - Nature (2009), Time to act, Vol. 458, Issue no. 7242, 30 April 2009, http://www.nature.com/nature/journal/v458/n7242/pdf/4581077a.pdf. The Nature journal is an international weekly journal.

[2] - ITU. 2006. World Telecommunication/ICT Development Report 2006. Measuring ICT for social and economic development. ITU. Geneva. 206 pp.

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still scarce; it is hoped that this paper will stimulate further discussions and research on the topic and dialogue between the environment and ICT communities on promoting green and cool ICT starts in earnest.

As such, this study is organized as follows. Section 2, Literature Review is developed. In Section 3, Theoretical Framework is developed . In Section 4 We shall give a statistical test of the structure model .Results and discussion are given in Section 5,6 which is followed by a conclusion in Section 7.

Literature Review

In reviewing the literature on the impact of ICTs on the environment, there are two trends that can be distinguished. On the one hand, there is an increasing amount of literature that reports on the benefits of ICTs from the perspective of ICT proponents. The results of these assessments, which are sometimes based on second hand research or on predictions, suggest that ICTs can mitigate environmental impacts, especially those related to energy consumption, GHG emissions and the use of natural resources. Some but not all of this research comes from what may be called the ICT industry as well as individuals and organizations that are very enthusiastic about the use of ICTs and that are proponents of the information society. A second approach is based on primary research on the impact of ICTs on the environment. This approach is still in its infancy and results are not definitive as there has been relatively little research undertaken on this issue to date. So the environmental effects of ICT have been an active topic of research. ICT sector is of interest because it makes it possible to achieve reductions in GHG emissions in other sectors by providing solutions that may substitute travel, transport, physical products, and so forth (e.g., Berkhout and Hertin 2000; Hilty et al.2000).

Lan Yi, Hywel R. Thomas(2007) attempted to provide a review of the current state of the art of how e-business/ICT affects the environment. Through his study" A review of research on the environmental impact of e-business and ICT" . The work reviewed is in various forms including journal papers and thesis which have been peer-reviewed, as well as other resources such as projects and project reports,conference and symposia, and websites. It is claimed that the research examined has captured the most important work to date, either for a general knowledge of this new area or for background study by experts carrying out future research. The review has found that the currently dominant approach is either a micro-level case study approach or a macro-level statistical approach. It is concluded that a more predictive and empirical model, which can be applied within a sector of society, should be more beneficial in the long term. This approach should help simulate potential impacts resulting from changes of indicators, so that positive effects can be promoted and negative ones alleviated proactively, rather than knowing and accepting outcomes passively.

John Houghton (2009) in his study " ICT and the environment in developing countries: opportunities and developments" explored how the Internet and the ICT and related research communities can help tackle environmental challenges in developing countries through more environmentally sustainable models of economic development, and examines the status of current and emerging environmentally friendly technologies, equipment and applications in supporting programs aimed at addressing climate change and improving energy efficiency. Discussion focuses on the role of ICTs in: (i) climate change mitigation (e.g. investing in smart transport and energy efficient infrastructure); (ii) mitigating other environmental pressures (e.g. biodiversity loss, water and soil pollution); (iii) climate change adaptation (e.g. adapting to rising sea levels, droughts, desertification); and (iv) international co-operation (e.g. technology transfer and the development of sustainable ICT value chains). This paper provided an overview and points to examples of current activities and opportunities in each of these areas.

Giulio, Cainelli. Giovanni ,Marin Massimiliano Mazzanti(2010) explored the links between two pieces of evidence in order to provide insights on how ICT affects environmental related performance. Sector and firm original data are used to compensate various lacks of data at different level of analyses (e.g. emissions typically lacking at firmlevel).First, in these study under the umbrella of the notion of Milgrom and Roberts (1995) complementarity how variously specification of ICT integrated innovations in firms are correlated to other innovations and specifically to green techno organizational innovation, including CSR environmental behavior and R&D green efforts. They exploit a rich CIS like dataset on 555 northern Italian firms covering 2006-2008 and issues such as technological innovation, training, eco innovations, ICT, international strategies. They thus analyzed the (eventually joint) drivers of both eco innovations and ICT innovations along a wide array of specifications. The second piece of the tale is the analysis of Italian NAMEA data (1990-2007, 29 branches, 14 manufacturing sectors) merged with trade, investments and R&D data. The theoretical framework is that of IPAT /EKC models where the aim is to analyze the drivers of delinking at sector level (with dependant variable emissions on output). Within investments, we newly added ICT sector based investments in order to shed light on the sector/dynamic effects of ICT investments on emission efficiency and decoupling performance.

Lorenz Erdmann and Lorenz M. Hilty(2010) studied scenario analysis of the future impacts of ICT applications on GHG emissions. they concluded that forthcoming macroeconomic studies could strengthen the state of the art in environmental ICT impact modeling (1) by accounting for the dynamics of new ICT applications and their first-, second-, and third-order effects on a global scale, (2) by reflecting the error margins resulting from data uncertainty in the final results,and (3) by using scenario techniques to explore future uncertainty and its impacts on the results.

Jens Malmodin, Åsa Moberg, Dag Lund´en, G¨oran Finnveden, and Nina L¨ovehagen(2010) studied assesses the electricity use and greenhouse gas(GHG) emissions related to the ICT and entertainment &media (E&M) sectors at sector level, including end users, and thus complements information on the product level. GHGs are studied in a life cycle perspective, but for electricity use, only the operational use is considered. The study also considers which product groups or processes are major contributors. Using available data and extrapolating existing figures to the global scale for 2007 reveals that the ICT sector produced 1.3% of global GHG emissions in 2007 and the E&M sector 1.7%. The corresponding figures for global electricity use were 3.9% and 3.2%, respectively. The results indicate that for the ICT sector, operation leads to more GHG emissions than manufacture, although impacts from the manufacture of some products are significant. For the E&M

sector, operation of TVs and production of printed media are the main reasons for overall GHG emissions. TVs as well as printed media, with the estimations made here, led to more GHG emissions on a global level in 2007 than PCs (manufacture and operation). A sector study of this type provides information on a macro scale, a perspective easily lost when considering, for example, the product-related results of life cycle assessments. The macro scale is essential to capture changes in total consumption and use. However, the potential of the ICT sector to help decrease environmental impacts from other sectors was not included in the assessment.

Jussi Ahola, Toni Ahlqvist, Miikka Ermes, Jouko Myllyoja & Juha Savola(2010) in his study "ICT for Environmental Sustainability,Green ICT Roadmap" used the term ICT for environmental sustainability or environmentally sustainable ICT, instead of green ICT, and defined it as: Use of ICT for optimising societal activities in order to improve environmental sustainability. The roadmap is divided into three themes. Empowering people means using ICT to raise people's awareness of the environmental impact of their actions and to channel their behaviour in a more environmentally-friendly direction. Extending natural resources involves reducing the use of diverse environmentally unsustainable re-sources through ICT-based solutions. Optimising systems refers to minimising the environmental load of diverse systems by optimising their operation. As a synthesis, they identified four focal topics within the roadmap themes that are most promising for further investigation. These are: 1) environmentally sustainable consumption, 2) smart energy and buildings, 3) lifecycle efficient production, and 4) optimised and adaptive networks.

Theoretical Framework of the Study

Today the impact of ICT on the Environment is one of the broadest issues.The issue of Information and Communication Technologies (ICT) and Environment is complex and multifacete. In a larger perspective, ICTs and the environment have a much deeper connection. ICT can play both positive and negative roles in environmental sustainability (Hargroves k. C.and Smith H., (2005)). This paper want to show that the positive impact of ICT on the environment is immeasurably high and so, outweighs its potentially negative impact. ICT in the environment sector is often used to:

• make a valuable contribution to sustainable environmental management by improving monitoring and response systems, facilitating environmental activism and enabling more efficient resource use.

• reduce the consumption of energy, water and other essential natural resources through more efficient agriculture and industrial procedures.

• play an important role in the fight against pollution—not only by providing more useful information, but also by enabling population decentralization and large-scale telecommuting.

• Improve accountability of energy consumption and carbon emissions.

• Offer smart and integrated approaches to energy management of systems and processes, including benefits from both automation and behavioral change and are alternatives to high carbon activities, across all sectors of the economy.

• ICT in the environment sector is often used to communicate traditional forms of environmental knowledge to communities and to facilitate the citizen monitoring of environmental issues" (http://www.wsis.ethz.ch/).

• ICTs enable the development of innovative green technologies, production of greener products and optimization of the ways of their delivery (Reisch 2001). Another positive effect of ICTs is that a huge amount of information concerning the environment circulates via the Internet, thus developing public awareness of environmental issues.

At a higher level, ICTs enable greater participation and involvement of human beings with activities that are critical to protecting the environment at several levels. At the institutional level, they enable less use of paper and better resource management, networking, and information exchange. For researchers, they provide tools that are critical in observation, simulation, and analysis of environmental processes; and for educators, they make learning and teaching more effective, while extending educational resources to a larger community.

• ICT is also being deployed extensively to monitor and respond to environmental , disasters in developing countries. ITU (2008), noted six application categories in_developing countries as follows:

1)*Environmental observation*: terrestrial (earth, land, soil, water), ocean, climate and atmospheric monitoring and data recording technologies and systems.

2)*Environmental analysis*: once environmental data have been collected and stored, various computational and processing tools are required to perform the analysis.

3)*Environmental planning*: at the international, regional and national level, planning makes use of the information from environmental analysis as part of the decision- making process for the purpose of policy formulation and planning.

4)*Environmental management and protection*: involves everything related to managing and mitigating impacts on the environment as well as helping adapt to given environmental conditions. This includes resource and energy conservation and management systems, GHG emission management and reduction systems and controls, pollution control and management systems and related methodologies, including mitigating the ill effects of pollutants and man-made environmental hazards.

5)*Impact and mitigating effects of ICT utilization*: producing, using and disposing of ICTs require materials and energy and generate waste, including some toxic waste in the form of heavy metals

6)*Environmental capacity building*: efforts to improve environmental conditions rely on the actions of individuals and organizations. Capacity building includes efforts to increase public awareness of environmental issues and priorities, the development of professionals, and integrating environmental content into formal education.[3]

Empirical Framework of the Study

Variable Description

The environmental quality influence,scale and TECHNICAL effects(Grossman and Krueger (1995)) .In this study, environmental quality is measured by CO_2 emissions, while GDP per capita is considered as an index of scale effect. As income grows, the scale of an economy tends to become larger. A country requires increasing output, therefore more inputs and more natural resources, in addition, more output also implies increased wastes and emissions as a by-produce of the economic activity which worsens the environmental quality.

[3] - Source: ITU (2008) *ICTs for e-Environment: Guidelines for developing countries, with a focus on climate change*, ITU, Geneva, p25

This is the so-called scale effect. Also emission can influence the TECHNICAL effect.Technical Progress in pollution abatement has two effects: 1) lower input use per unit of output produced or improved environmental management 2) lower emissions per unit of input used. In this study, Information and communication technology expenditure (% of GDP) had been considered as TECHNICAL effect. The impact of trade on the environmental quality is also considered. This paper uses the export+ import/gdp as index of trade.

Country Selection

The selected countries for this study are divided into 2 categories of 28 developed and 15developing countries, using World Bank's definition of country classification based on gross national income (GNI) per capita[4].The set of 28 developed countries include Australia, Austria, Canada, Switzerland, Czech Republic, France, Germany, Denmark, Spain, Finland, France, United Kingdom, Greece, Hungray Italy, Japan, South Korea, Mexico, Netherlands, Norway, New Zland, Poland, Portugal, Russian Federation, Slovnia, Sweden, and United States. The set of 15 developing countries include Argentina, Armenia, Ecuador ,China, Egypt, India, Indonesia, Iran, Malaysia, Philippines, Tunisia, Thailand, Ukraine, Brazil, and Vietnam.

Model Specification

We will first clarify some methodological points related to our analysis. First, We specify the reduced-form equation by basically following the traditions of the literatures like Grossman and Krueger (1993) and Selden and Son (1994), and adding appropriate variables in accordance with our analytical interests. Another methodological innovation in this study is to adopt a dynamic panel model. Halkos (2003) pointed out that a static model is justified either if adjustment processes are really very fast or if the static equation represents an equilibrium relationship, argued that since the assumption that the data are stationary is incorrect, and we are not expecting a very fast adjustment for estimating the EK curve, a statistically sound approach requires estimating a dynamic model. Following the argument of Halkos (2003), we construct a dynamic panel model by inserting a lagged dependent variable as a regressor into the equation for materializing a partial adjustment toward equilibrium emissions level.

Given the above analytical interests mentioned ,variable description and country clusters into developed and developing blocks, the model specification is as under:

$$LN\ CO_{2it} = \alpha_i + \beta 1 LN\ (GDP)_{it} + \beta 2 LN\ (GDP)^2_{it} + \beta 3\ LN(ICT)_{it} + \beta 4\ LN(TRADE)_{it} + \beta 5\ LN\ CO_{2it-1} + \varepsilon_{it} \quad (1)$$

where, $LNCO_{2it}$ indicates the logaritm carbon dioxide emissions in country i at time t.LN GDP_{it} is the GDP per capita in country i at time t, while $LN(GDP)^{\wedge 2}{}_{it}$ is the square of GDP in country i at time t. $LNTRADE_{it}$ is the logaritm trade dependence ratio expressed as the sum of exports and imports to GDP, for country i at time t. $LNICT_{it}$ is the logaritm ict expenditure /gdp in country i at time t . Finally, ε_{it} is the error term.

The above equation is estimated in a dynamic panel data framework where the subscripts i and t stand for cross-sectional identifier and time period identifier respectively. The coefficients β1, β2, β3, β4 and β5 is determined for the 2 groups of developed and developing countries.

[4] -(http://go.worldbank.org)

Empirical Analysis

Stationarity

Stern (2004) indicates that in most EKC research, very little emphasis is given on the statistical properties of the data used. Accordingly, as a first step in this paper, the six series:LN CO2,LN GDP per capita,LN and LNTRADE were tested for stationarity in the panel framework using Levin-Lin-Chu test (2002). According to the test, if the error terms in a panel are independent and identically distributed and there are no fixed effects, then the panel regression unit root t-statistic converges to the standard normal distribution. However, if individual fixed effects are present, or there is serial correlation in the residuals, the test statistic converges to a non-central normal distribution that requires either a correction to the t-statistic or revised tables of critical values (t-star). The results of the panel unit root test are provided in Table 1 and Table 2 below.

Table 1: Panel unit root test results: Developed countries

Variable	Coefficient	P-value	Inference
Ln co_2	-8,41812	0,0000	Stationary
lnGDP	-5,20194	0,0000	Stationary
lnGDP^$_2$	0.03801	0,4742	Non-Stationary
lnTR	-3,50309	0,0002	Stationary
lnICT	-3,34508	0,0000	Stationary

Table 2: Panel unit root test results: Developing countries

Variable	Coefficient	P-value	Inference
Ln co_2	-8,41812	0,0000	Stationary
lnGDP	-5,20194	0,0000	Stationary
lnGDP^$_2$	0.03801	0,4742	Non-Stationary
lnTR	-3,50309	0,0002	Stationary
lnICT	-3,93893	0,8060	Non-Stationary

The above results show that the unit root tests do not reject the null hypothesis of a unit root for all the series. In other words, if a series is non-stationary, it violates the standard Gauss Markov assumptions. Further, it is evident from the above unit root test results for both developed and developing countries that some of the series are stationary even at the original level of the series.

Panel cointegration test

According to previews disscution,, we proceed to test $LNco_2$ and LN GDP per capita ,LN ICT, LNTRADE, LN CO_2it-1 respectively, for cointegration in the data using the heterogeneous panel cointegration test developed firstly by Pedroni (1997,1999). This test allows for cross-sectional interde-pendencewith different individual effects. Pedroni (1999) suggeststwo types of residual-based tests. As for the first type, four tests are distributed as being standard normal asymptotically and are based on pooling the residuals of the regression for the within-group;they are the panel v-statistic, panel r-statistic, panel PP-statisticand panel ADF-statistic. With the second type, three tests are also distributed as being standard normal asymptotically but are based on pooling the residuals for the between-group; they are the group r-statistic, group PP-statistic and the group ADF-statistic. These statistics are based on estimators that simply average the indivi-dually estimated coefficients for each member, and each of these tests is able to accommodate individual specific short-run dynamics, individual specific fixed effects and deterministic trends, aswell as individual specific slope coefficients (Pedroni, 2004). Our objective here is to test the variables for cointegration to determine whether there is a long-run relationship to control for in the econometric specification. With the findings in the Monte Carlo simulation experiments, Pedroni (1999, 2004) showed that the panel ADF-statistic and group ADF-statistic tests have better small-sample properties than the others, and hence, they are more reliable. In addition, Kao (1999) studied residual-based tests for cointegration regression in panel data, we also use Kao residual cointegration test to investigate the null of no cointegration in dynamic panels.Table 3 presents the panel cointegration test results. The Panel ADF-statistic and Group ADF-statistic mostly strongly reject the null of no cointegration significantly at less than 10% critical values,and Kao residual cointegration test also strongly reject the null of no cointegration significantly at 1% critical value. Hence we generally obtain strong evidence of cointegration among these series. Thus, it can be predicted that LN Co2 and and LN GDP per capita ,LN ICT, LNTRADE variables move together in the long-run. Thus, there is a steady-state relationship between these variables. The next step is to estimate this relationship.

Table 3: Panel cointegration

Pedroni Cointegration	Developed countries	Developing countries
Panel v-Static	3.328***	2.584***
Panel rho-Static	-0.612	-1.220
Panel pp-Static	-1.894*	-2.185***
Panel ADF-Static	-3.675***	-2.729
Group rho-Static	1.609	0.105
Group pp-Static	1.008	-1.675**
Group ADF-Static	-4.378***	-2.765***

Note: Statistics are asymptotically distributed as normal. The variance ratio test is right-sided, while the others are left-sided.***,**and *rejects the null of no cointegration atthe 1%, 5% and 10% level, respectively. For the formulas used in the panel cointegration test statistics, it is described in details in Pedroni (1999, 2004) .

Model Estimation Results

Table 4,5 list the results of the GMM estimation per capita on carbon dioxide emissions (co2) in two groupes countries.

Table 4: Results of Results of Dynamic Panel Estimation by GMM :Developed countries

Independent variable	Cofitionet	t-static
lnGDP	0.001962*	2.010753
lnGDP^^{2}	-1.49E-06*	-2.115785
lnTR	-0.022534*	-3.906157
Ln ICT	-0.000664*	-6.189938
LNCO$_2$(-2)	0.804743 *	10.09354

- Significant at 5% confidence level.

Table 5: Results of Dynamic Panel Estimation by GMM: Developing countries

Independent variable	Cofitionet	t-static
lnGDP	0.001509*	2.146042
lnGDP^^{2}	-2.05E-05*	-3.298895
lnTR	0.000734*	5.664162
Ln ICT	-0.000293*	-3.883480
LNCO$_2$(-2)	0.300153*	6.783819

* Significant at 5% confidence level.

Table 5and Table 6 indicate that the inclusion of the lagged dependent variable of the emissions per capita proved to be positively discernable, thus imply inertia in the level of the emissions and justify forming the dynamic panel model. The Sargan tests do not suggest rejection of the instrumental validity at conventional levels for any cases estimated. [5]

The coefficients for GDP per capita are significant and positive while that of GDP per capita-square is significant and negative, reinforcing the EKC theory. This is true for both the developed and the developing (selected) group of countries. The coefficients for Information and communication technology expenditure (% of GDP), which was used as a proxy for ict advancement, is significant and negative for both group of countries, indicating a scope for reduction in carbon emission through ict progress. However, the directional relationship between openness indicator and carbon emissions is different between the developed and the developing country, although significant in both. It comes with a negative sign for developed countries and a positive sign for developing countries. This reinforces our earlier hypothesis of advancement in trade being associated to shifting of production base for polluting industries to the developing world from developed countries due to cost advantages and difference in environmental regulations. (pollution Haven Hypotheses).

Conclusions

This paper investigates the relationship between ICT and environmental pollution based on the EKC hypothesis. By applying the EKC hypothesis, we established a panel-data model to link ICT and several control variables with co_2 emission. In this model, we used co_2 as the environmental indicator. Economic growth and other control variables such as ICT and trade are used in our Dynamic Panel Estimation by GMM-model for 43 developed and developing countries for 2003–2008. The results solidly support the existence of an EKC for co_2 emission. That is, co_2 emission increases faster than income at early stages of development and slows down relative to GDP growth at higher income levels.

For the selected control variables all variables were significant. trade had a different effect on co_2 in developed and developing countries.

The empirical results appear to support the notion that no unique relationship exist between trade and the environment across all countries and pollutants.The difference in average emission levels between two regions mainly comes from the following reason; Shifting of polluting industries from developed to developing countries due to cost advantage and relaxed environmental regulations, could lead to higher pollution in the latter countries. While in the developed countries, this relationship works in the opposite direction.

Although the ICT factor is a negative one to pollution for the both regions, the levels of impact are different, in developed and developing countries. in developed countries ICT is more important factor to reducing pollution than developing countries.in the developed countries, when the Information and communication technology expenditure (% of GDP) are increased the co_2 pollution decrease in a greater rate. Still, developing countries need to be made more aware of the importance of acting on the environment and of seeking financial and technical support to do so.

The international development community also needs to understand the role ICTs can play in helping to manage the environment for sound and sustainable development and to mitigate and adapt to the effects of climate change.

There is a need for more awareness among decision-makers of the benefits of using ICTs to deal with environmental issues. Finally, while reaching any consensus over global pollution reduction seems to benefit one country over the other in the short run, countries should be focusing on long run environmental reduction benefits.

[5] - see Annex 1 and 2

Annex 1: Results of Results of Dynamic Panel Estimation by GMM :Developed countries

Dependent Variable: LNCO2
Method: Panel Generalized Method of Moments
Transformation: Orthogonal Deviations
Date: 11/20/11 Time: 18:51
Sample (adjusted): 2005 2008
Periods included: 4
Cross-sections included: 28
Total panel (balanced) observations: 112
White period instrument weighting matrix
Instrument list: @DYN(CO2,-1) TRADE(-1) ICT

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNCO2(-1)	0.804743	0.079729	10.09354	0.0000
LNY	0.001962	0.000976	2.010753	0.0476
LNY^2	-1.49E-06	7.05E-07	-2.115785	0.0374
LNICT	-0.000664	0.000107	-6.189938	0.0000
LNTRADE	-0.022534	0.005769	-3.906157	0.0002

Effects Specification

Cross-section fixed (orthogonal deviations)

Mean dependent var	0.000625	S.D. dependent var	0.877269
S.E. of regression	1.137246	Sum squared resid	106.0530
J-statistic	6.677307	Instrument rank	14.000000

Annex 2: Results of Results of Dynamic Panel Estimation by GMM :Developing countries

Dependent Variable: LNCO21
Method: Panel Generalized Method of Moments
Transformation: Orthogonal Deviations
Date: 11/20/11 Time: 19:08
Sample (adjusted): 2005 2008
Periods included: 4
Cross-sections included: 15
Total panel (balanced) observations: 60
White period instrument weighting matrix
Instrument list: @DYN(ICT1,-1) ICT1 TRADE1(-1)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNCO21(-1)	0.300153	0.044245	6.783819	0.0000
LNY1	0.001509	0.000703	2.146042	0.0363
LNTRADE1	0.000734	0.000130	5.664162	0.0000
LNICT1	-0.000293	7.54E-05	-3.883480	0.0002
LNY1^2	-2.05E-05	6.20E-06	-3.298895	0.0017

Effects Specification

Cross-section fixed (orthogonal deviations)

Mean dependent var	-0.011243	S.D. dependent var	0.103374
S.E. of regression	0.186528	Sum squared resid	1.913603
J-statistic	9.255985	Instrument rank	15.000000

Reference

- Berkhout P, Muskens HG, Jos C, Velthuijsen JW. Defining the rebound effect. Energy Policy 2000;28(6–7):425– 32.

-Erdmann L, Wü rtenberger F (2003) The future impact of ICT on environmental sustainability: identification and global description of economic sectors. Institute for Prospective Technological Studies. Seville. Available at: http://fiste.jrc.ec.europa.eu/download/interim_report_1_final.pdf

- Grossman, G. and Krueger, A.(1995). Economic growth and the environment. Quarterly Journal of Economics 110, 353–77.

-Grossman G.M. and Krueger A.B.(1993). Environmental Impacts of a North American Free Trade Agreement, in Garber P. (ed.) The US-Mexico Free Trade Agreement. MIT Press,Cambridge, MA, 13-56.

- Halkos, G.E. (2003). Environmental Kuznets Curve for sulfur: evidence using GMM estimation and random coefficient panel data models. Environment and Development Economcis, 8, 581-601.

-Hargroves K. C. and Smith H. (Eds.). (2005). The National Advantage of Nations: Business Opportunities, Innovation and Governance in the 21st Century. Section 3: The regulatory measure response. London: Sterling, VA, (182-188).- initiative. July 2001, from http://www.opt-init.org/framework/pages/2.2.5.html

-Hausman J.(1978). Specification Tests in Econometrics. Econometrica. Vol. 43, 727-738.

- Houghton, J.W. and Welsh, A. (2009) .Australian ICT Trade Update 2009, Australian Computer Society, Sydney. Available http://www.cfses.com

-Hilty LM, Ruddy T, Schultless D.(2000). Resource intensity and dematerialisation potential of information society technologies. Solothurn: Solothurn University of Applied Sciences North-Western Switzer-land and the authors; January 2000. p. 12.

-ITU.(2006). World Telecommunication/ICT Development Report 2006. Measuring ICT for social and economic development. ITU. Geneva. 206 pp.

-Jussi Ahola, Toni Ahlqvist, Miikka Ermes, Jouko Myllyoja & Juha Savola(2010). ICT for Environmental Sustainability. Green ICT Roadmap. Espoo 2010. VTT Tiedotteita – Research Notes 2532. 51 p.

-Kao, C., Chiang, M-H., and Chen, B.(1999) "International R&D Spillovers: An Application of Estimation and Inference in Panel Cointegration," A pdf version is available. GAUSS program for this paper is downloadable in Text format. OXFORD BULLETIN OF ECONOMICS AND STATISTICS, 1999.

- L Erdmann, L M Hilty (2010) Scenario Analysis: Exploring the Macroeconomic Impacts of Information and Communication Technologies on Greenhouse Gas Emissions Journal of Industrial Ecology 14: 5. 824-841

-Levin A., Lin C.F. and Chu C.S.(2002). Unit Root Tests in Panel Data: Asymptotic and Finite Sample Properties. Journal of Econometrics. Vol 108, 1-24.

-Malmodin, J. (2009) „Life cycle assessments of ICT,‟ OECD Conference on ICTs, the environment and climate change, Helsingor. Available http://itst.media.netamia.net/ict2009/video.php?tab=demand

-Nature (2009), Time to act, Vol. 458, Issue no. 7242, 30 April 2009,http://www.nature.com/nature/journal/v458/n7242/pdf/4581077a.pdf. The Nature journal is an international weekly journal.

- Pedroni, P. (1995). Panel cointegration: Asymptotic and finite sample properties of pooled time series test with an application to the PPP hypothesis.Indiana University Working Papers in Economics, Vol. 95-013.

-Pedroni, P. (1999). Critical values for cointegration tests in heterogeneous panels with multiple regressors. Oxford Bulletin of Economics and Statistics, 61(4), 653−670.
-Plepys A (2002) The grey side of ICT. Environment impact assess rev 22:509–23
-Reisch LA (2001) The Internet and sustainable consumption: perspectives on a Janus face. J Consum Policy 24(3/4):251–286
- Reisch LA(2001). The Internet and sustainable consumption: perspectives on a Janus face. J Consum Policy 2001;24:251– 86.
-Stern D.I.(2004). The Rise and Fall of The Environmental Kuznets Curve. World Development, Vol. 32, 1419–1434.
-T. Selden and D. Song (1994), "Environmental Quality and development: Is there a Kuznets Curve for Air Pollution Emissions?", Journal of Environmental Economics and Management, 27(2), 147-162
- Yi, L. and Thomas, H.R. (2007) „ A review of research on the environmental impact of e-business and ICT,‟ Environment International 33, pp841-849.
- World Bank.(2010). http://go.worldbank.org/K2CKM78CC0. Accessed on May 23, 2010. World Bank, Washington DC