#2014-089

Technology & environment: Some possible damaging effects of technological change in advanced and opulent societies

Mario Coccia

TECHNOLOGY & ENVIRONMENT:

SOME POSSIBLE DAMAGING EFFECTS OF TECHNOLOGICAL CHANGE IN ADVANCED AND OPULENT SOCIETIES

Mario Coccia[1]
UNITED NATIONS UNIVERSITY -THE MAASTRICHT ECONOMIC AND SOCIAL RESEARCH INSTITUTE
ON INNOVATION AND TECHNOLOGY (UNU-MERIT),
CNR -- NATIONAL RESEARCH COUNCIL OF ITALY
& ARIZONA STATE UNIVERSITY
Current Address:
UNU-MERIT -Keizer Karelplein 19
6211 TC Maastricht, The Netherlands
E-mail: mario.coccia@ircres.cnr.it

Abstract.

An interesting problem is the analysis of effects of the predominant impact of technological change on the health of societies. This study considers technological change as the human activity that generates a huge impact on societies and causes environmental disorders affecting the health of population. In particular, technical innovations support the industrialisation and human development, which by a social change based on population growth, mass production and consumption, and resources depletion, engenders pollution and several environmental carcinogens. This study shows that a main effect of the critical impact of technological change on societies is the high cancer incidence of population living in industrialised areas of opulent and advanced countries. Vital empirical evidence and linkages between observed facts endeavour to explain the major relationships concerning the interactions among technology, ecosystems and the health of societies.

Keywords: Technology, Industrialisation, Pollution, Cancer, Human Development, Social Change, Environmental Change.

JEL classification: O33; O44; I15; Q53

The problem

Technological change is a human activity of adaptation and learning to take advantage of important territorial opportunities and of better chances for survival and livelihood in the presence of scarce resources and/or consequential environmental threats (Coccia, 2014a). Technological innovations are the main drivers of patterns of economic growth, and as a consequence productivity, employment and progress (Coccia, 2005a; 2009; 2009a; 2012b; Bajmócy and Gébert, 2014). However, this fruitful relationship between technological change and economic growth for human development is increasingly questioned in several scientific fields (*cf.* Bajmócy and Gébert, 2014; Glikson, 2013; Bowman *et al.,* 2011). As a matter of fact, the human activity of technical change, during its developmental path, tends to cause environmental damage (*cf.* Constant *et al.,* 2014, p. 230; Foley *et al.,* 2013; Chin *et al.*, 2013; Coccia, 2012b, 2014b; Coccia, 2009). A fundamental question concerning the role of technology in modern advanced and opulent society is: What is the main effect of the predominant impact of technological change on ecosystems and society?

This paper confronts this problem by developing a conceptual framework, which endeavours to analyse, by vital empirical evidence, some effects induced by technical change on modern society and population. The study here provides fruitful results that show the huge negative impact of human development, by technological change, on ecosystems and societies (*cf.* Coccia, 2013; Ramis *et al.,* 2011*;* Irigaray *et al.,* 2007; Belpomme *et al.,* 2007; 2007a; Shine, 2004). The research is carried out by a philosophy of science based on scientific realism (Thagard, 1988, p. 145; *cf.* Kukla, 1998) in order to support the theoretical framework concerning human interactions among technological change, ecosystems and societies.

The Backdrop of Prior Research and Related Works

The study concerning the human impact, by technological innovations, on the environment and society begins in 1860s (Marsh, 1864). In particular, environmental and social change, driven by hu-

man development, have increased since the first industrial revolution, started in England in 1750s, such that several scholars debate the concept of a new geological epoch called Anthropocene[2] (Crutzen and Stoermer, 2000; Zalasiewicz *et al.,* 2011). Chin *et al.* (2013, p. 1) argue that: "Changes in physical, biological, and chemical processes in soils and waters have resulted from human activities that include urban development, industrialisation, agriculture and mining, and construction and removal of dams and levees". Crutzen and Stoermer (2000), and Steffen *et al.* (2007) argue that the main effects of human activity on environment start with the industrial age in the 18th Century, which supports the acceleration of climate change from 1900s. Foley *et al.* (2013, p. 83) also claim that: "at around 1780 AD. . . this time marks the beginning of immense rises in human population and carbon emissions as well as atmospheric CO_2 levels, the so-called 'great acceleration' ". Coccia (2005; 2005a) argues that the waves of industrialisation are driven mainly by a vital human activity based on changes in the techno-economic paradigms, general purpose technologies and radical innovations, which have an enormous impact on industries, population, environment and societies. Phillips (2008, p. 722) claims that in current world there are: "bigger technological creations . . . having bigger impacts on people and societies". The history shows that the industrialisation of Europe and the USA, driven by technological change, and the general socio-economic progress of countries has generated wellbeing but also a massive increase of environment change by pollution and environmental diffusion of some environmental mutagens and carcinogens (*e.g.* pollutants, pesticide in agriculture, several chemicals, asbestos, food processed or chemically preserved, etc.), whose effects persist in the long run (Steingraber, 1997; *cf.* Ausubel *et al.,* 2001; Rivers, 2003).

Constant *et al.* (2014) study the effect of endogenous population growth on accumulation of factors during the industrialisation and argue that pollution and economic growth have an evolution in the same direction. In particular, scholars show that the economic growth, based on new technology,

---

[2] Crutzen and Stoermer (2000) argue that the globe is in a new geological era called *Anthropocene:* current geological epoch where there is a huge and predominant impact of human activities on earth and atmosphere.

often causes environmental disorders (Ausubel *et al.,* 2001; Rivers, 2003; Collins, 1994). This result is due to industrialisation that, by a progressive urbanisation, new needs and habits of societies, generates both human development and pollution: population growth 'overpopulation' generates more consumption, resources depletion, and as a consequence, pollution and environmental change (Rivers, 2003, p. 409; Constant *et al.*, 2014).

In fact, the industrialisation and economic growth spur a mass production of numerous goods and services to satisfy the several needs of human development. This high production, on large scale, generates environmental change by air pollution due to several emissions of fine particulate, which have damaging effects on ecosystems, living being and societies. Wang and Zhao (2011) claim that concentrations of industrial air pollutants and fine atmospheric particulates can be the carrier of toxic and carcinogenic pollutants (*e.g.* heavy metals, SO_2, etc.) that are considered main causes of serious health diseases such as lung cancer. Pope *et al.* (2002) show that each 10 $\mu g/m^3$ increase in fine particulate air pollution[3] tends to be associated with a 6% increase in all-cause of mortality. Beelen *et al.* (2013) show a 7% increase in natural cause mortality each $5\mu g/m^3$ increase in $PM_{2.5}$ concentration[4], whereas Raaschou-Nielsen *et al.* (2013) claim an 18% increase in lung cancer incidence for each 5 $\mu g/m^3$ increase in $PM_{2.5}$ concentration. Instead, Steingraber (1997) shows the potential role of industrial pollution and pesticide use in causing cancer. Ausebel *et al.* (2001, p. 134*ff*) analyse the relation death and human environment and show that heart disease and cancer are growing and could be a leading cause of death in USA about 2015.

Bray *et al.* (2013) have analysed the global cancer transition by the The Human Development Index (HDI- it considers the education, life expectancy and national income of population across countries). In particular, the study by Bray *et al.* (2013) shows that medium-HDI and high HDI countries tend to have a higher incidence of breast, prostate and colon-rectum cancer (*cf.* Sankaranarayanan *et al.,* 2010; Farmer *et al.*, 2010). Vineis and Wild (2014, p. 551) confirm that the higher clinical diag-

---

[3] µ=micro=10^{-6}

[4] $PM_{2.5}$ = Particulate Matter up to 2.5 micrometres in size.

noses of new cancer cases for people dying in high-HDI countries, where the technological change is higher, in comparison to low-HDI countries.

Hence, a main effect of the technological change on society is the growing cancer of population in more developed areas, where the huge impact of human activity and development engenders a critical environmental change (*cf.* Coccia, 2013; U.S. National Cancer Institute, 2014).

Conceptual framework

The thesis of this study is based on an abduction *à la* Peirce: the human development by technological change breeds some negative effects on ecosystems causing a higher incidence of cancer across societies.

Concept

Technological change of higher intensity is a human activity, originated in tepid zone of the globe, of adaptation and learning to take advantage of important territorial opportunities and of better chances for survival and livelihood in the presence of scarce resources and/or consequential environmental threats (Coccia, 2014a).

Technological change supports human development and also tends to generate environmental change.

Assumptions

☐ Geographical areas with high human development (advanced societies) have higher technical change, which supports industrialisation and generates a main impact on ecosystems and societies.

☐ The intensity of human activity, based on technical change, in geo-economic areas can be measured by R&D investments and number of patents (main proxies of human development and progress; *cf.* Coccia, 2009a; 2007; 2014; Moser, 2013).

☐ A main effect of technological change on societies can be measured by the cancer incidence of population (Belpomme *et al.,* 2007; 2007a; Coccia, 2013).

The conceptual framework of this study, which endeavours to explain the linkage from human development, to technological change and environmental damaging causing cancer in societies, is in the scheme of Figure 1.
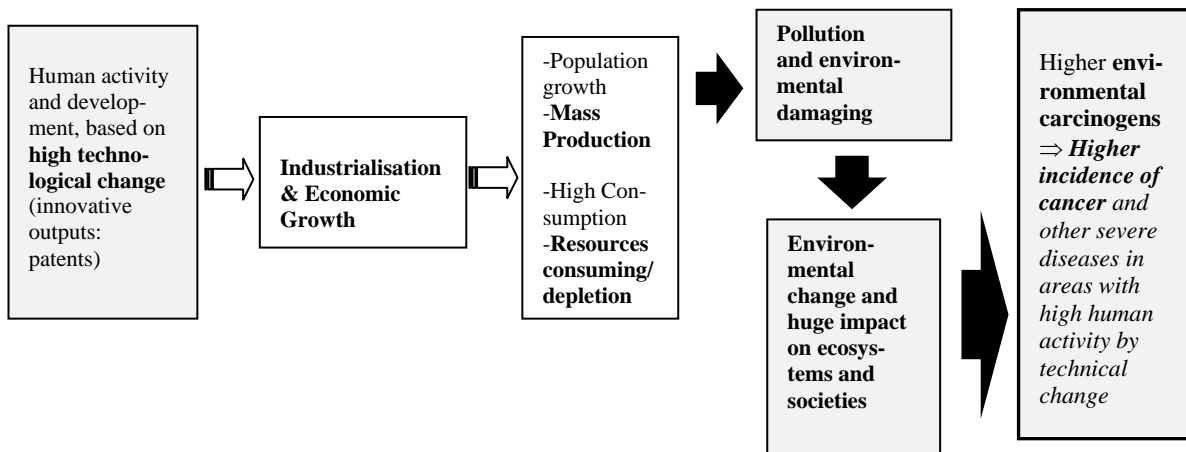

Figure 1. Linkages of the effects of human activity and development, by technological change, on ecosystems and societies.

Figure 1 shows that human activity and development generates patterns of fruitful technological innovation (high innovative outputs measured by patents and R&D intensity) that support industrialisation; Industrialisation and economic growth spur mass production, high consumption and resources depletion (*cf.* Rivers, 2003). This linkage breeds environmental change generating pollution, environmental damaging and, as a consequence, main impacts on ecosystems causing a higher carcinogens and incidence of cancer across societies.

Working Hypothesis

The human activity of technical change has a huge and continuous impact on ecosystems and societies. The hypothetical-deductive approach *à la* Hempel (1965) is based on the following working hypothesis (*HP θ*), which this study intends to test:

$HP\theta$: Human development based on high technological change generates main impacts

on ecosystems causing a higher incidence of cancers in societies.

The purpose of the present study is to ascertain whether statistical evidence supports the hypothesis

($HP\theta$).

Study design and methodology

Data and sources

- The study considers data over a period from 1960 to 2012.

- The indicators of the research and their sources are in table 1.

Table 1. Data and sources

Indicators	VARIABLES
A proxy of human development in geographical areas is the technological change measured by:	• *R&D Expenditure as % GDP (1960-2006)ϕ:* Expenditures for R&D are current and capital expenditures on the creative and systematic activity that increase the stock of knowledge. This includes fundamental, applied research and experimental development work leading to new devices, products, or processes. • *Patent Applications of Residents and Non Residents (1960-2006) ϕ*: Patents of residents and non-resident that are applications filed through the patent cooperation treaty procedure or with a national patent office for exclusive rights to an invention − a product or process that provides a new way of doing something or offers a new technical solution to a problem.
Negative impact of human development by technological change, on ecosystems and societies is measured by:	• *Brain, Breast, Cervix, Colon, Liver, Lung, Pancreas, Prostate Cancer - Incidence in ASR W (2010)*:* Age-standardised rate (W) is the number of new cases (Incidence) per 100 000 persons per year. An age-standardised rate is the rate that a population would have if it had a standard age structure. Standardisation is necessary when comparing several populations that differ with respect to age because age has a powerful influence on the risk of cancer.
Other main indicators	• *Computed Tomography(2010)♠:* Total density per million population: Computed Tomography • *Population growth (1960-2006)ϕ:* Annual population growth rate for year t is the exponential rate of growth of midyear population from year t-1 to t, expressed as a percentage.

Source of data: * Ferlay *et al.* (2013); GLOBOCAN 2012; ϕ World Bank Indicators 2008; ♠ World Health Organization 2010.

According to Hunt and Gauthier-Loiselle (2011, p. 32): "the purpose of studying patents is to gain insight into technological progress, a driver of productivity growth, and ultimately economic growth". Another main indicator of human development is the R&D intensity (*cf.* Moser, 2013; Coccia, 2010; 2012).

This study has obtained the data of table 1 for 108 countries of two main different geographical areas with different level of economic development (*see* Appendix A). The data in the sample have subjected to horizontal and vertical cleaning, excluding some countries with

missing values and outliers. As some initial variables do not have normal distributions, a logarithmic transformation is performed to adjust these distributions in order to correctly apply statistical analyses.

□ *Statistical analysis to support HPθ*

To determine the impact of human development, by technical change, on societies, this study considers two sets of geographical areas of societies (*see* Appendix A).

- High Human Development Societies with High Impact of Technical Change on Ecosystems: these societies are identified by Organisation for Economic Co-operation and Development (OECD) countries that tend to have administrations that foster prosperity through technological innovations and economic growth. They tend to have higher human development by high innovative outputs (Number of Patents and R&D Intensity), which generate a huge impact on ecosystems and societies.

- Lower Human Development Societies with Lower Impact of Technical Change on Ecosystems and societies: These Societies are identified by Non OECD countries that are in general poorer and with lower technological change (lower innovative outputs measured by patents), thereby lower impact on ecosystems and societies.

A main negative impact of human development, based on higher technological change, is measured and assessed by the incidence of cancer in societies of different geographical areas.

In particular, this study has compared the arithmetic mean of cancer incidence in these two matching sets of geographical area of society cohorts— **OECD** *vs.* **NON OECD**.

The statistical hypotheses are:

H_0: average incidence of cancer in **OECD** = average incidence of cancer in **NON OECD**

H_1: average incidence of cancer in **OECD** $\neq$ average incidence of cancer in **NON OECD**

This study applies the analysis of variance (ANOVA) and the expectation is that ANOVA rejects statistical H_0 in favour of H_1: advanced and opulent societies with higher human development by technological change (*i.e.* OECD member countries) generate higher impacts on ecosystems causing a higher incidence of cancer.

In order to check the results, the further statistical analysis is based on:

- test of Welch and Brown-Forsythe of robustness for equality of mean (this test is a preferable test to F when it is not valid the hypothesis of equivalence of the variance);

- decomposition of the total deviation of the whole set considering each typology of cancer in two cohort sub-sets of **OECD** and **NON OECD**

$$DEV(X) = \sum_{k=1}^{r} \sum_{i=1}^{N_k} (x_{ki} - \mu)^2 = \sum_{k=1}^{r} \sum_{i=1}^{N_k} (x_{ki} - \mu_k)^2 + \sum_{k=1}^{r} N_k (\mu_k - \mu)^2$$

$$DEV(X) = \sum DEV(X_k) + \sum N_k (\mu_k - \mu)^2 \qquad [2]$$

Equation [2] shows that Total Deviation of whole set = Deviation within sub-sets (WTH) +Deviation between (BTW) sub-sets.

In addition, patterns of technological innovation are generating better healthcare based on diffusion of apt health technology to detect the cancer (*e.g.* computed tomography) and surveillance program of diseases (Coccia, 2013). In order to consider this factor, a partial correlation analysis was carried, between the key variables, controlling both number of computer tomography across countries and population growth.

Evidence and Results

Figures 2-3 and Table 2 show that OECD countries have higher human development measured by

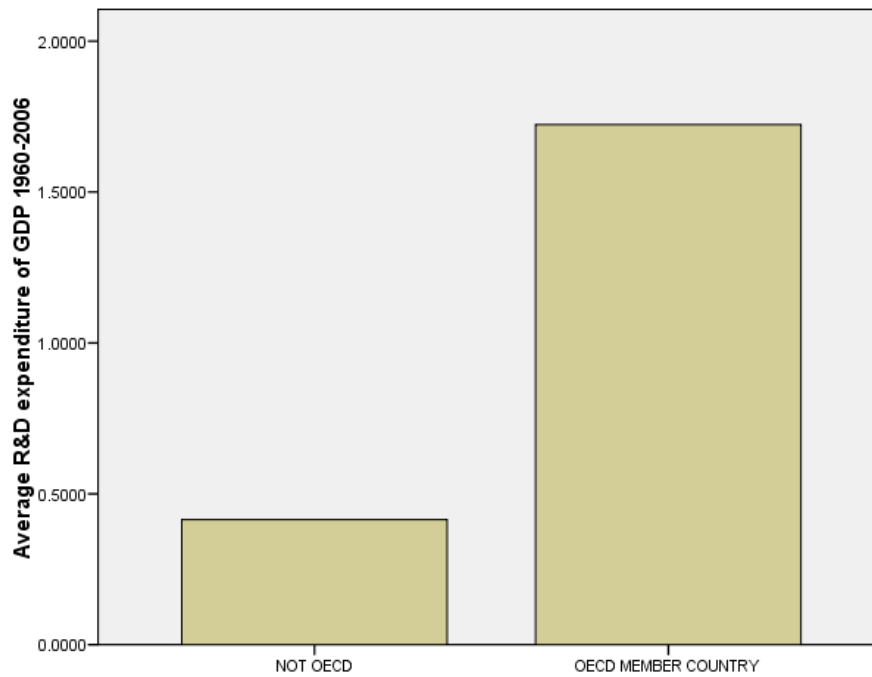average technological outputs and R&D intensity higher.

Figure 2. Arithmetic mean of R&D Expenditure as % of GDP (strong indicator of human development and higher technological change in societies) in OECD and non OECD countries 1960-2006
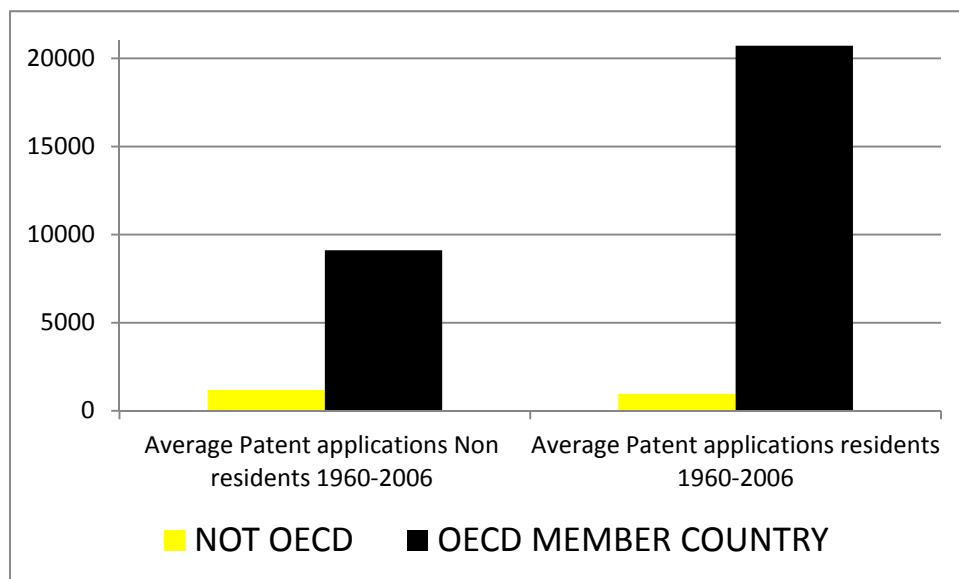

Figure 3. Arithmetic mean of Patent applications of residents and non-residents (another strong indicator of human development and higher technological change in societies) in OECD and non OECD countries 1960-2006

11

However, Table 2 also show, by descriptive statistics, that OECD member countries with higher human development and technological change (measured by main indicators of innovative outputs) are prone to have a higher cancer incidence in comparison with non-OECD countries.

Table 2. Descriptive statistics of **OECD** (High Human Development Societies) *vs.* **NON OECD**

Variables	OECD: High Human Development Societies			NON OECD: Low Human Development Societies		
	N.	Mean	Std Dev.	N.	Mean	Std Dev.
1. ASR W BRAIN Incidence*	30	**5.5**	1.4	77	3.9	2.3
2. ASR W BREAST Incidence*	30	**76.8**	20.9	77	40.0	18.7
3. ASR W CERVIX Incidence*	30	8.9	4.5	77	21.0	14.5
4. ASR W COLON Incidence*	30	**31.7**	8.5	77	14.3	9.6
5. ASR W LIVER Incidence*	30	5.0	3.8	77	7.2	9.9
6. ASR W LUNG Incidence*	30	**29.9**	8.0	77	15.5	10.7
7. ASR W PANCREAS Incidence*	30	**6.8**	1.5	77	3.8	2.5
8. ASR W PROSTATE Incidence*	30	**76.9**	31.7	77	29.1	25.7
9. R&D Expenditure of GDP % (average) 1960-2006φ	30	**1.7**	0.9	77	0.4	0.6
10. Patent Applications of Residents (average) 1960-2006 φ	30	**20,719.4**	64,542.3	77	959.3	3,597.6
11. Patent Applications of Non Residents (average) 1960-2006 φ	30	**9,106.8**	20,489.8	77	1,180.5	3,154.2

Note: * Elaboration on data by Ferlay *et al.* (2013); GLOBOCAN 2012; φ World Bank 2008; <u>Higher values are Under-lined and in bold</u>. For meaning of acronyms see table 1.

Bar diagram in Figure 4 shows that HIGH human development Societies (OECD), based on High Technology, tend to generate, in general, a higher average incidence of main typologies of cancer (except cervix and liver cancer). Hence, it seems that a high human development and technological change can breed a strong environmental change and negative impacts on ecosystems causing a higher cancer incidence.
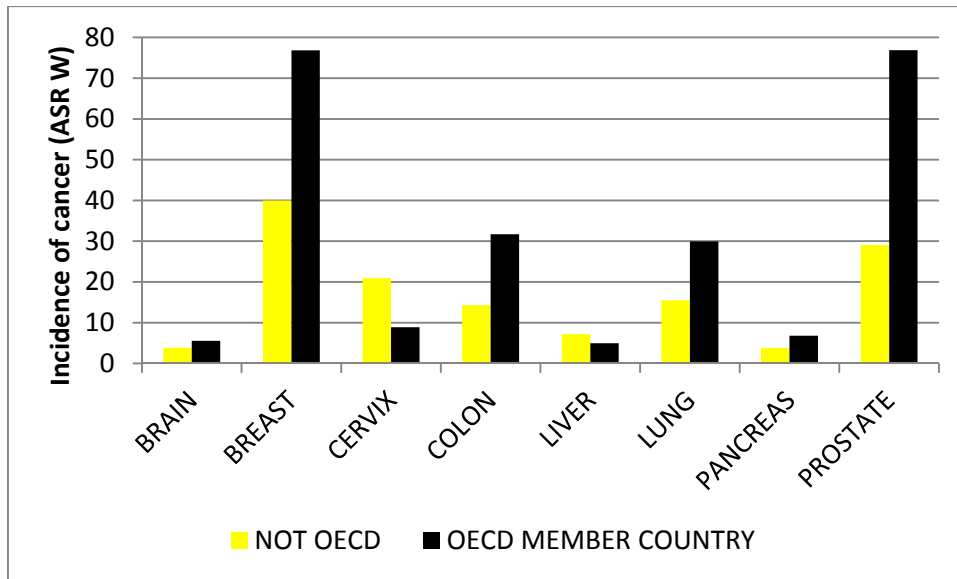
Figure 4. Higher cancer incidence in OECD (or OECD countries-High Human development Area) 1960-2006

Figure 5 shows a geographical map of the globe that focuses on this main finding: total cancer inci-

dence, measured by ASR (*see* table 1 for meaning), in societies with Very high human development

index[5] (represented by some OECD countries with also very high technological change and outputs)

is equal to 316, *vice versa* societies with low human development index have a incidence of all can-

cers equal to 102.7 ASR (W) per 100,000 people; hence low human development in some societies,

due to low technical change, seems to support a lower environmental change and impact on ecosys-

tems, thereby cancer incidence is about −67.5% than richer and opulent societies!

---

5 The Human Development Index (HDI) is a comparative measure of life expectancy, literacy, education, standards of living, and quality of life for countries worldwide. It is a standard means of measuring well-being. It is used to distinguish whether the country is a developed, a developing or an underdeveloped country. OECD countries have a Very High Human Development Index; *vice versa* Non OECD.
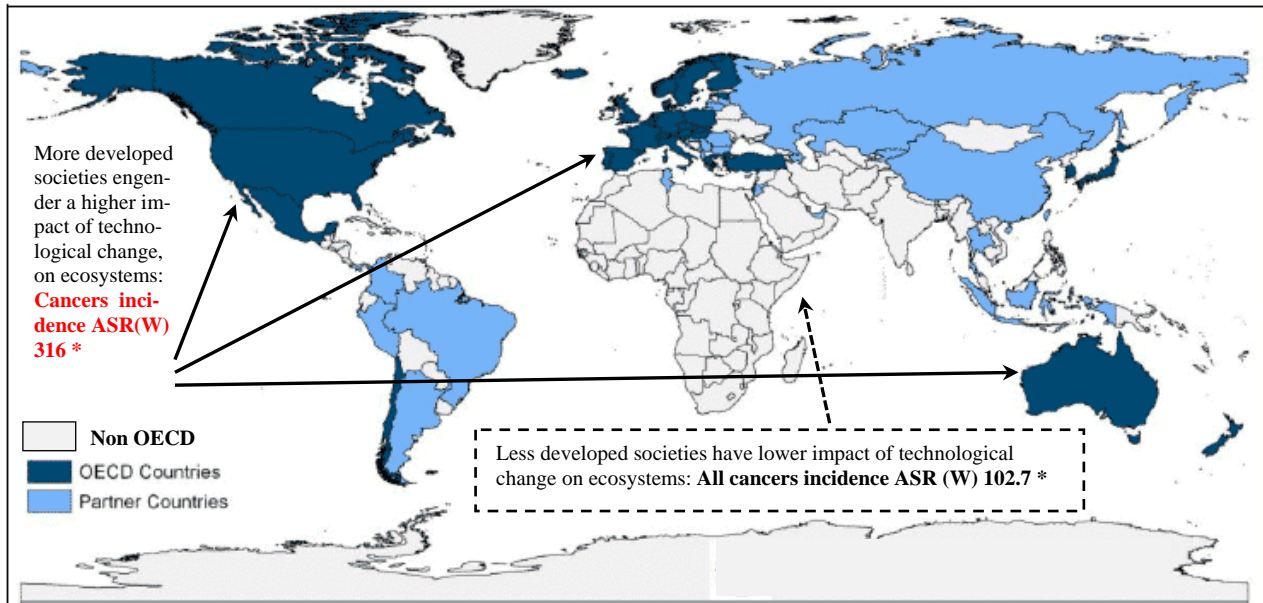
Figure 5: HIGH developed societies with High Impact of Technology on Ecosystems (OECD countries and partners) *vs.* NON OECD (in light grey). * *Source:* Elaboration on data by Ferlay *et al.* (2013). For acronyms and meaning see table 1.

Considering the average cancer incidence (in logarithmic values) in OECD *vs.* NON OECD, table 3 displays that the difference of arithmetic mean is significant at 1‰, except for liver cancer. This empirical evidence is confirmed when a difference of variance is assumed, applying Welch & Brown-Forsythe test (*cf.* Tab. 4).

Table 3. ANOVA per cancer in OECD *vs.* NON OECD

	Variable: Arithmetic mean of *LN incidence of cancer ASR W*							
				Cancer				
	Brain	Breast	Cervix	Colon	Liver	Lung	Pancreas	Prostate
F	14.29	51.50	21.58	46.94	1.08	29.66	28.35	44.03
Sign.	(0.00)	(0.00)	(0.00)	(0.00)	(0.30) ψ	(0.00)	(0.00)	(0.00)

Note: *df*= 106 for all cancers; ψ=not significant

Table 4. Test of robustness of equality across arithmetic mean of group
(Welch and Brown-Forsythe) in OECD *vs*. NON OECD

Not valid the assumption of equal variance

Variable: Arithmetic mean of *LN incidence of cancer ASR W*

	Brain	Breast	Cervix	Colon	Liver	Lung	Pancreas	Prostate
					Cancer			
Welch & Brown-Forsythe*	31.06	79.96	34.10	82.90	1.51	60.05	63.48	75.75
Sign.	(0.00)	(0.00)	(0.00)	(0.00)	(0.22) ψ	(0.00)	(0.00)	(0.00)

Note: * the value of the statistic is equal between the two tests. *F* has a asymptotic distribution; ψ=not significant

Decomposition of the total deviation further confirms these very important findings (Table 5): High values of the deviation *between groups* (OECD *vs*. NON OECD) for all cancer incidences (see rows in bold).

Table 5. Decomposition of the total deviation per cancer typology
across OECD and NON OECD Areas

	BRAIN	BREAST	CERVIX	COLON	LIVER*	LUNG	PANCREAS	PROSTATE
			Cancer incidence data in ASR W across OECD and NON OECD Area					
DEV WTN NON OECD	409.29+	26,692.87+	16,035.64+	6,984.05+	8.46+	8,673.85+	460.12+	50,065.37+
DEV WTN OECD	57.35+	12,717.08+	578.30+	2,119.83+	1.49+	1,834.76+	64.03+	29,152.36+
DEV BTW	**60.16=**	**29332.50=**	**3155.07=**	**6534.69=**	**0.10=**	**4509.44=**	**192.67=**	**49280.02=**
DEV Total	526.80	68742.45	19769.01	15638.57	10.06	15018.05	716.82	128497.75
DEV WTN NON OECD %	77.69+	38.83+	81.12+	44.66+	84.12+	57.76+	64.19+	38.96+
DEV WTN OECD %	10.89+	18.50+	2.93+	13.56+	14.86+	12.22+	8.93+	22.69+
DEV BTW%	**11.42=**	**42.67=**	**15.96=**	**41.79=**	**1.02=**	**30.03=**	**26.88=**	**38.35=**
DEV Total %	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
μ Non OECD	3.87	39.97	20.96	14.30	0.70	15.47	3.80	29.07
σ Non OECD	2.32	18.74	14.53	9.59	0.33	10.68	2.46	25.67
μ OECD	5.54	76.83	8.87	31.70	0.63	29.93	6.79	76.85
σ OECD	1.41	20.94	4.47	8.55	0.23	7.95	1.49	31.71
μ Total	4.34	50.30	17.57	19.18	0.68	19.53	4.64	42.47
σ Total	2.23	25.47	13.66	12.15	0.31	11.90	2.60	34.82

Note: DEV=Deviation; WTN=within groups; BTW= between groups.*Logarithmic value; μ=arithmetic mean; σ=Standard deviation; These results are based on Equation [2].

Table 6 –Partial Correlations of key variables (Control Variable: LNComputed Tomography)

| | | Logarithm Variables (Control Variable is Computed Tomography) | | | | | | |
		ASR W BREAST Incidence	ASR W CERVIX Incidence	ASR W COLON Incidence	ASR W LIVER Incidence	ASR W LUNG Incidence	ASR W PANCREAS Incidence	ASR W PROSTATE Incidence
LN R&D Expenditure of GDP % (average) 1960-2006	*r*	0.43	-0.29	0.44	-	0.46	-	0.22
	Sign.	0.00	0.03	0.00	-	0.00	-	0.10
	df.	57	57	57	-	57	-	57
LN Patent Applications Residents (average) 1960-2006	*r*	-	-	0.31	0.28	0.48	0.28	-
	Sign.	-	-	0.02	0.03	0.00	0.03	-
	df.	-	-	57	57	57	57	-

Note: - is for not significant values

Table 7 – Partial Correlations (Control Variable: LN Computed Tomography and Population growth average 1960-2006)

| | | Logarithm Variables (Control Variable: LN Computed Tomography and Population growth average 1960-2006) | | | | | | |
		ASR W BREAST Incidence	ASR W CERVIX Incidence	ASR W COLON Incidence	ASR W LIVER Incidence	ASR W LUNG Incidence	ASR W PANCREAS Incidence	ASR W PROSTATE Incidence
LNR&D Expenditure of GDP % (average) 1960-2006	*r*	0.44	-0.33	0.46	-	0.48	-	0.22
	Sign.	0.00	0.01	0.00	-	0.00	-	0.10
	df.	55	55	55	-	55	-	55
LN Patent Applications Residents (average) 1960-2006	*r*	-	-	0.294	0.306	0.479	0.259	-
	Sign.	-	-	0.027	0.021	0.000	0.052	-
	df.	-	-	55	55	55	55	-

Note: - is for not significant values

Table 6 and 7 show partial correlation analyses, *controlling* screening technology and population growth average: the results tend, in general, to show a general positive association with main determinants of technological change across countries.

In brief, the statistical evidence seems in general to support the systematic difference of higher cancer incidence in OECD societies than NON OECD ones. This socio-economic fact can be explained by higher diffusion of several environmental carcinogens and pollutants in ecosystems of advanced societies, induced by industrialisation based on high technological change, causing a negative impact on ecosystems and higher cancer incidence.

Phenomena Explained

Irigaray *et al.* (2007) argue the growing incidence of a variety of cancer after the World War II in advanced countries, that is due to several factors such as ageing of the population, progress in health technology, expansion in diagnostic and screening programs, and in particular to environmental carcinogens driven by increasing industrialisation and technical change. This study shows a strong positive concordance between higher incidence of cancer and richer countries (*e.g.* OECD area) where the impact of technological change is higher on environment and societies. This finding is due to a strong linkage that runs from changes in the techno-economic paradigm (originated by industrial revolutions), wide diffusion of technological innovations, expansion of industrialisation, increasing economic growth, overpopulation, higher pollution, conspicuous consumption to environmental damaging causing cancer. In short, technological change as human activity tends to generate main negative impacts on ecosystems causing higher incidence of a variety of cancers.

In fact, Irigaray *et al.* (2007, pp. 640-641) claim that:

> There is evidence that the environment has changed over the time period preceding the recent rise in cancer incidence, and that this change, still continuing, included the accumulation of many new carcinogenic factors in the environment . . . Genetic susceptibility to cancer due to genetic polymorphism cannot have changed over one generation and actually favours the role of exogenous factors through gene-environment interactions . . . . the involuntary exposure to many carcinogens in the environment, including microorganisms (viruses, bacteria and parasites), radiations (radioactivity, UV and pulsed electromagnetic fields) and many xenochemicals, may account for the recent growing incidence of cancer and therefore that the risk attributable to environmental carcinogen may be far higher than it is usually agreed. Of major concern are: outdoor air pollution by carbon particles associated with polycyclic aromatic hydrocarbons; indoor air pollution by environmental tobacco smoke, formaldehyde and volatile organic compounds such as benzene and 1,3 butadiene, which may particularly affect children and food contamination by food additives and by carcinogenic contaminants such as nitrates, pesticides, dioxins and other organochlorines. In addition, carcinogenic metals and metalloids, pharmaceutical medicines and some ingredients and contaminants in cosmetics may be involved. Although the risk fraction attributable to environmental factors is still unknown, this long list of carcinogenic and especially mutagenic factors supports our working hypothesis according to which numerous cancers may in fact be caused by the recent modification of our environment.

Ayres (1998) argues fossil fuels have been fundamental drivers of past and present human development, and that radical technological innovations are essential to confront natural resource scarcities (*cf.* Sterner *et al.,* 1998, p. 254). In particular, economies in the post-World War II, based on coal and petroleum-based feedstock (*cf.* Campbell, 2002), have generated several patterns of technological innovation in heavy organic chemical industry, synthetic materials and petrochemicals (*cf.* Ruttan, 1997, p. 1523*ff; cf.* Ruttan, 2001). This technology change has

supported industrialisation in Western countries and an increasing wellbeing (Coccia, 2005; 2005a). However, this economic growth is increasingly questioned in other fields of economics because *some* effects of technology are expressed negatively on ecosystems and societies by spreading carcinogenic and especially mutagenic factors (*e.g.* radioactivity, pulsed electromagnetic fields, xenochemicals, carbon particles associated with polycyclic aromatic hydrocarbons, etc.), food pollution by additives and carcinogenic contaminants (such as nitrates, pesticides, dioxins and other organochlorines; *cf.* Bajmócy and Gébert, 2014). These factors of the technological change induce damages on ecosystems and, as a consequence, carcinogenesis that may account for the growing incidence of cancer across societies with higher human development (*cf.* Belpomme *et al.,* 2007; Ausubel *et al.* 2001). Zeliger (2011, p. 435, Ch. 32) shows that: "incidence rates are highest in the industrially developed areas of the world, where people are exposed to higher levels of carcinogenic chemicals. In each case, those people living in areas with lower incidences for a particular cancer demonstrate increased rates when they migrate to areas with higher incidences, further demonstrating the cancer causative effects of environmental and occupational exposures to toxic chemicals".

In fact, cancer incidences (the number of new cases occurring annually) increased by 85% from 1950 to 2001 (Zeliger, 2011, p. 434). *As genetic changes cannot account for this rapid increase in cancer incidence, for genes do not change that rapidly, thereby this effect is due to the huge impact of human activity and development, driven by technological change, industrialisation and mass production that generate environmental diffusion of toxic chemicals (such as solvents, pesticides, dioxins, etc.) and increase the incidence of cancers* (*cf.* also Rivers, 2003).

Hence, technological change supports human development based on industrial expansion and mass production for opulent societies, however it also generates resource-consuming and environmental damaging causing a higher cancer incidence for societies (*cf.* Motel *et al.,* 2014, pp.479-480). In other words, human activity and development, by technological innovations, is prone to environmental effects damaging ecosystems by pollutants that induce the diffusion of carcinogens

and increase the incidence of cancer across industrialised societies.

Discussion and Concluding Observations

Nowadays, it is increasing the debate and also criticisms of the dominating economic approach growth-oriented due to a negative impact on ecosystems and societies of a massive industrialisation, mass production and consumption, driven by technological change and human development (Rivers, 2003; Chin *et al.*, 2013; Bajmócy and Gébert, 2014).

The findings of this study are mainly two:

- ☐ *Firstly*, the human activity of technological change, generating environmental and social change, is based mainly on path-breaking innovations:

  - General Purpose Technologies (GPTs) that are characterised by pervasiveness, inherent potential for technical improvements, and 'innovational complementarities', giving rise to increasing returns-to-scale such as the steam engine, the electric motor, and semiconductors (Bresnahan and Trajtenberg, 1996, p. 83, original emphasis);

  - Changes of new technological systems that impact several parts of the economy such as the clusters of synthetic materials innovation and petrochemical invention (*cf.* Freeman and Soete, 1987, p. 56; Dicken, 2011; Coccia, 2005; 2005a);

  - Changes in the techno-economic paradigms, such as steam engine and electric power that are: "clusters of radical and incremental innovation and embraces several 'new technological systems' …. may be described as a 'technological regime' …and of 'natural trajectories' in technology" (Freeman and Soete, 1987, p. 56, original emphasis). This innovation revolutionises all existing markets (Coccia, 2005a, p. 124);

- ☐ *Secondly*, a main effect of wide diffusion of technological innovation (higher technological outputs) across advanced societies (OECD countries) is the environmental damaging that increases carcinogenic agents in ecosystems and, as a consequence, cancer incidence of population. *Vice versa*, societies with lower technological change have lower incidence of cancer.

In fact, industrialisation, driven by higher technological innovations, of advanced and opulent societies tends to spread in the ecosystems several environmental carcinogens such as asbestos (that leads to lung cancer), aromatic amines (bladder cancer; Zeliger, 2011), benzidine (several cancers), benzene (leukaemias, *cf.* Richardson, 2008), arsenic, aflatoxin, polychlorinated biphenyls, radon, as well as metals (chromium, cadmium, nickel, and beryllium), exposure to diesel exhaust, diesel generators in residential settings, electromagnetic fields, *etc.* (Vineis and Wild, 2014, pp. 552-554). This study shows that technological change is a human activity that has a main role for human development and wellbeing, though it is generating environmental change and a huge negative impact on ecosystems and societies causing higher cancer incidence. In fact, the human development, based on the acceleration of higher technological change and innovative outputs, is supporting, after the World War II, the growing incidence of a variety of cancer in advanced societies (Irigaray *et al.,* 2007).

The solution to this negative impact of human development on ecosystems, driven by technological change and competitive markets, may be to implement industrial policies with environmental concerns in order to support sustainable technological innovations for a fruitful environmental change (*cf.* Sterner and Coria, 2012). It may be also important to apply disclosure strategies to increase the availability of information on pollution in order to design new technology and pollution control policy for reducing the negative impact on ecosystems and environment (Tietenberg, 1998). Sustainable technologies improve several aspects of ecosystems and can reduce cancer incidence in modern societies (*cf.* Ausubel *et al.,* 2001). In fact, some scholars consider the relationship between human development and negative impact on environment as a an inverted U-shaped curve – environmental Kuznets curve – because the technological change increases the pollution in the early stages of economic development, but beyond some levels of wealth, wealthier and advanced societies can support environmental improvements (Coccia, 2014b).

In brief, human development should be engaged in sustainable technological innovations of lung-

run perspective to reduce coal and petroleum-based economies and, as a consequence, the negative impact of human interactions on ecosystems for the real well-being of future generations. According to Linstone (2010, p. 1417, original emphasis): "the global future will strongly depend on our willingness to take near-term action for a sustainable long-term future" (*cf.* Rosen, 2010).

In all, the interaction among technological change, ecosystems and society is becoming more and more complex and it might prove difficult to identify all causes and effects of the old and new technology. The results of this paper have tried to provide, through empirical evidence, a degree of closeness to true effects on societies induced by technological change. However, analyses like this study, are problematic when we know that other things are often not equal, because the effects of technological change on ecosystems and society have an infinite set of true consequences and causes, such that no results will be true in all situations.

Appendix A

OECD Member countries
Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Korea, Luxembourg, Mexico, The Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States.

NON OECD member countries
Algeria, Argentina, Armenia, Azerbaijan, Bangladesh, Belarus, Bosnia and Herzegovina, Botswana, Brazil, Bulgaria, China, Colombia, Croatia, Cuba, Cyprus, Ecuador, Egypt Arab Rep., Ethiopia, Gambia, Georgia, Ghana, Guatemala, Haiti, Honduras, India, Indonesia, Iran Islamic Rep., Iraq, Kazakhstan, Kenya, Rep. Kyrgyz, Republic Latvia, Lesotho, Libya, Lithuania, Macedonia-FYR, Madagascar, Malawi, Malaysia, Malta, Mauritius, Moldova, Mongolia, Morocco, Nicaragua, Pakistan, Panama, Peru, Philippines, Romania, Russian Federation, Saudi Arabia, Serbia and Montenegro, Singapore, South Africa, Sri Lanka, Sudan, Swaziland, Syrian Arab Republic, Tajikistan, Tanzania, Thailand, Trinidad and Tobago, Tunisia, Turkmenistan, Uganda, Ukraine, Uruguay, Uzbekistan, Venezuela, Vietnam, Zambia, Zimbabwe.

References

Ausubel J. H., Meyer P. S., Wernick I. K (2001) "Death and the human environment: the United States in the 20th century" *Technology in Society*, *vol. 23, n. 2, pp. 131-146*

Ayres R. U. (1998) "Towards a Disequilibrium Theory of Endogenous Economic Growth" *Environmental and Resource Economics,* vol. 11, n. 3–4, pp. 289–300.

Bajmócy Z., Gébert J. (2014) "The outlines of innovation policy in the capability approach", *Technology in Society*, vol. 38, pp. 93-102

Beelen R., Raaschou-Nielsen O., Stafoggia M., et al. (2013) "Effects of long-term exposure to air pollution on natural-cause mortality: an analysis of 22 European cohorts within the multicentre ESCAPE project", *Lancet*; published online Dec 9. http://dx.doi.org/10.1016/S0140-6736(13)62158-3.

Belpomme D., Irigaray P., Hardell L., Clapp R., Montagnier L., Epstein S., Sasco A.J.(2007) "The multitude and diversity of environmental carcinogens", *Environmental Research*, vol. 105, n. 3, pp. 414-429.

Belpomme D., Irigaray P., Hardellc L., Clapp R., Montagnier L., Epstein S., Sasco A. J. (2007a) "Review-The multitude and diversity of environmental carcinogens", *Environmental Research*, vol. 105, n. 3, pp. 414–429.

Bowman D.M., et al., (2011) "The human dimension of fire regimes on Earth", *Journal of Biogeography,* vol. 38, n. 12, pp. 2223–2236.

Bray F., Ren J.-S., Masuyer E., Ferlay J. (2013) "Global estimates of cancer prevalence for 27 sites in the adult population in 2008", *International Journal of Cancer*, vol. 132, n. 5, pp. 1133–45.

Bresnahan T.F., Trajtenberg M. (1996). "General purpose technologies: 'engines of growth'?", *Journal of Econometrics, Annals of Econometrics*, vol. 65, n. 1, pp. 83–108.

Campbell C.J. (2002) "Petroleum and People", *Population and Environment*, vol. 24, n. 2, pp. 193-207.

Chin A., Fu R., Harbor J., Taylor M. P., Vanacker V. (2013) "Anthropocene: Human interactions with earth systems", *Anthropocene*, vol. 1, pp. 1-2.

Coccia M. (2005) "Technometrics: Origins, historical evolution and new direction" in *Technological Forecasting & Social Change*, vol. 72, n. 8, pp. 944-979.

Coccia M. (2005a) "Measuring Intensity of technological change: The seismic approach" in *Technological Forecasting and Social Change*, vol. 72, n. 2, pp. 117-144.

Coccia M. (2007) "A new taxonomy of country performance and risk based on economic and technological indicators" in *Journal of Applied Economics,* vol. 10, n. 1, pp. 29-42.

Coccia M. (2009) "Measuring the impact of sustainable technological innovation", *International Journal of Technology Intelligence and Planning,* vol. 5, n. 3, pp. 276-288.

Coccia M. (2009a) "What is the optimal rate of R&D investment to maximize productivity growth?" in *Technological Forecasting & Social Change,* vol. 76, n. 3, pp. 433-446.

Coccia M. (2010) "Democratization is the driving force for technological and economic change" in *Technological Forecasting & Social Change,* vol. 77, n. 2, pp. 248-264.

Coccia M. (2012) "Driving forces of technological change in medicine: Radical innovations induced by side effects and their impact on society and healthcare", *Technology in Society,* vol. 34, n.4, pp.271-283.

Coccia M. (2012a) "Evolutionary growth of knowledge in path-breaking targeted therapies for lung cancer: radical innovations and structure of the new technological paradigm", *International Journal of Behavioural and Healthcare Research,* vol. 3, ns. 3-4, pp. 273-290.

Coccia M. (2012b) "Political economy of R&D to support the modern competitiveness of nations and determinants of economic optimization and inertia", *Technovation,* vol. 32, n. 6, pp. 370–379.

Coccia M. (2013) "The effect of country wealth on incidence of breast cancer", *Breast Cancer Research and Treatment*, vol. 141, n. 2, pp. 225-229.

Coccia M. (2014) "Driving forces of technological change: The relation between population growth and technological innovation-Analysis of the optimal interaction across countries", *Technological Forecasting & Social Change,* vol. 82, n. 2, pp. 52-65.

Coccia M. (2014a) "The relation between geo-climate zones and technological outputs: technological change as a strategy of adaptation and learning to geo-economic environments", *Unpublished.*

Coccia M. (2014b) "Drivers and Contradictions of Technological Change in Advanced Societies, and New Directions of Path-breaking Anticancer Innovations Based on Nanotechnology and Biotechnology", *Clipper Conference 2014 Disruptive Innovations, Pivotal Moments and Crossroads*-Amsterdam, October 2-3, 2014.

Collins L. (1994) "Environmental performance and technological innovation: The pulp and paper industry as a case in point", *Technology in Society*, *vol. 16, n. 4, 1994, pp. 427-446*

Constant K., Nourry C., Seegmuller T. (2014) "Population growth in polluting industrialization", *Resource and Energy Economics*, vol. 36, n. 1, pp. 229-247.

Crutzen P.J., Stoermer E.F. (2000) "The Anthropocene", *Global IGBP Change Newsletter*, n. 41, pp. 17–18.

Dicken P. (2011) *Global shift, mapping the changing contours of the world economy,* Sage.

Farmer P., Frenk J., Knaul F.M., et al. (2010) "Expansion of cancer care and control in countries of low and middle income: a call to action", *Lancet,* vol. 376, n. 9747, pp. 1186–93.

Ferlay J., Soerjomataram I., Ervik M., Dikshit R., Eser S., Mathers C., Rebelo M., Parkin D.M., Forman D., Bray, F. (2013) *GLOBOCAN 2012 v1.0, Cancer Incidence and Mortality Worldwide: IARC CancerBase No. 11 [Internet].* Lyon, France: International Agency for Research on Cancer; 2013. Available from: http://globocan.iarc.fr, accessed on 19/06/2014.

Foley S. F., Gronenborn D., Andreae M. O., Kadereit J. W., Esper J., Scholz D., Pöschl U., Jacob D. E., Schöne B. R., Schreg R., Vött A., Jordan D., Lelieveld J.,. Weller C. G., Alt K. W., Gaudzinski-Windheuser S., Bruhn K. C., Tost H., Sirocko F., Crutzen P. J. (2013) "The Palaeoanthropocene – The beginnings of anthropogenic environmental change", *Anthropocene*, vol. 3, pp. 83-88.

Freeman C, Soete L. (1987) Eds. *Technical Change and full employment*, Basil Blackwell.

Glikson A. (2013) "Fire and human evolution: The deep-time blueprints of the Anthropocene", *Anthropocene*, vol. 3, pp. 89-92.

GLOBOCAN 2012. Available from http://globocan.iarc.fr/ (accessed June 2014)

Hempel C. G. (1965) *Aspects of Scientific Explanation.* The Free Press, NY.

Hunt J., Gauthier-Loiselle M. (2010) "How Much Does Immigration Boost Innovation?", *American Economic Journal: Macroeconomics*, vol. 2, n. 2, pp. 31–56.

Irigaray P., Newby J. A., Clapp R., Hardell L., Howard V., Montagnier L., Epstein S., Belpomme D. (2007) "Dossier : Cancer : Influence of environment Lifestyle-related factors and environmental agents causing cancer: An overview", *Biomedicine & Pharmacotherapy,* vol. 61, n. 10, pp. 640-658.

Kukla A. (1998) *Studies in Scientific Realism,* Oxford University Press, NY.

Linstone H. A. (2010) "Historians and complexity: trends vs. collapses?" *Technological Forecasting and Social Change*, vol. 77, n. 8, pp. 1415-1428.

Marsh G.P. (1864) *Man and Nature*. Reprinted in 1965. Harvard University Press, Cambridge.

Moser P. (2013) "Patents and innovation: evidence from economic history", *Journal of Economic Perspectives*, vol. 27, n. 1, pp. 23-44.

Motel P. C., Choumert J., Minea A. Sterner T. (2014) "Explorations in the Environment–Development Dilemma", *Environ Resource Econ.,* vol. 57, n. 4, pp. 479–485, DOI 10.1007/s10640-013-9745-9.

Phillips F. (2008) "Change in socio-technical systems: Researching the Multis, the Biggers, and the More Connecteds", *Technological Forecasting and Social Change*, vol. 75, n. 5, pp. 721-734.

Pope C., Burnett R., Thun M., et al. (2002) "Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution", *JAMA,* vol. 287, n. 9., pp. 1132–41.

Raaschou-Nielsen O., Andersen Z.J., Beelen R., et al. (2013) "Air pollution and lung cancer incidence in 17 European cohorts: prospective analyses from the European Study of Cohorts for Air Pollution Effects (ESCAPE). *Lancet Oncology,* vol. 14, n. 9, pp. 813–22.

Ramis R., Diggle P., Cambra K., López-Abente G. (2011) "Prostate cancer and industrial pollution Risk around putative focus in a multi-source scenario", *Environment International,* vol. 37, n. 3, pp. 577–585.

Richardson D.B. (2008) "Temporal variation in the association between benzene and leukemia mortality", *Environmental Health Perspective,* vol. 116, n. 3, pp. 370–74.

Rivers T. J. (2003) "Technology and the use of nature", *Technology in Society, vol. 25, n. 3, pp. 403-416*

Rosen R.A., Electris C., Raskin P.D. (2010), *Global Scenarios for the Century Ahead*, Tellus Institute.

Ruttan V. W. (1997) "Induced innovation, evolutionary theory and path dependence: sources of technical change", *The Economic Journal*, vol. 107 (*September*), pp. 1520-1529.

Ruttan V. W. (2001) *Technology, Growth and Development: An Induced Innovation Perspective,* Oxford University Press: New York.

Sankaranarayanan R., Swaminathan R., Brenner H., et al. (2010) "Cancer survival in Africa, Asia, and Central America: a population-based study", *Lancet Oncology,* vol. 11, n. 2, pp. 165–73.

Shine K.I. (2004) "Technology and health", *Technology in Society*, vol. 26, n. 2–3, pp. 137–48.

Steffen W., Crutzen P.J., McNeill J.R. (2007) "The Anthropocene: are humans now overwhelming the great forces of nature?", *AMBIO,* vol. 36, pp. 614–621.

Steingraber S. (1997) *Industrial pollution, pesticides, and cancer. Living Downstream. An Ecologist Looks at Cancer and the Environment.* Reading, Addison-Wesley, Massachusetts, *ISBN 0-201-48303-3.*

Sterner T., Coria J. (2012) *Policy instruments for environmental and natural resource management*, 2nd ed. RFF Press and Routledge, New York, NY.

Sterner T., Jeroen C. J., Van Den Bergh M. (1998) "Frontiers of Environmental and Resource Economics", *Environmental and Resource Economics,* vol. 11, n. 3–4, pp. 243–260.

Thagard P. (1988) *Computational Philosophy of Science,* The MIT Press, Cambridge, MA (USA).

Tietenberg T. (1998) "Disclosure Strategies for Pollution Control", *Environmental and Resource Economics,* vol. 11, n. 3–4, pp. 587–602.

U. S. National Cancer Institute (2013) http://www.cancer.gov/ (accessed January 2014)

Vineis P., Wild C. P. (2014) "Global cancer patterns: causes and prevention", *The Lancet*, vol. 383, n. 9916, pp. 549-557.

Wang S., Zhao Y. (2011) "Air Pollution and Lung Cancer Risks", *Reference Module in Earth Systems and Environmental Sciences*, from *Encyclopedia of Environmental Health*, pp. *26-38*, Current as of 10 December 2013.

World Bank (2008) *World Development Indicators on CD-ROM,* The World Bank, Washington D.C.

World Health Organization (2010), http://www.who.int/whosis/whostat/2010/en/ (accessed September 2014)

Zalasiewicz, J., Williams, M., Haywood, A., Ellis, M. (2011) "The Anthropocene: a new epoch of geological time?" *Philos. Trans. R. Soc. A*, vol. 369, pp. 835–841.

Zeliger H. (2011) *Human Toxicology of Chemical Mixtures-Toxic Consequences Beyond the Impact of One-Component Product and Environmental Exposures* (Second Edition), Elsevier Inc., ISBN: 978-1-4377-3463-8.

The UNU-MERIT WORKING Paper Series

2014-01 *The medium-term effect of R&D on firm growth* by Marco Capasso, Tania Treibich and Bart Verspagen

2014-02 *Diverse and uneven pathways towards transition to low carbon development: The case of diffusion of solar PV technology in China*Michiko Iizuka

2014-03 *User innovators and their influence on innovation activities of firms in Finland* by JariKuusisto, MerviNiemi and Fred Gault

2014-04 *Migration, remittances and household welfare in Ethiopia* by Lisa Andersson

2014-05 *Path-breaking directions of nanotechnology-based chemotherapy and molecular cancer therapy* by Mario Coccia and Lili Wang

2014-06 *Poor trends - The pace of poverty reduction after the Millennium Development Agenda*Richard Bluhm, Denis de Crombrugghe, Adam Szirmai

2014-07 *Firms' adoption of international standards: Evidence from the Ethiopian floriculture sector* by MuluGebreeyesu

2014-08 *School choice, segregation, and forced school closure*by Cheng Boon Ong andKristof De Witte

2014-09 *Gender difference in support for democracy in Sub-Saharan Africa: Do social institutions matter?*by MatyKonte

2014-10 *Why are women less democratic than men? Evidence from Sub-Saharan African countries* by Cecilia García-Peñalosa and MatyKonte

2014-11 *Tipping points? Ethnic composition change in Dutch big city neighbourhoods* by Cheng Boon Ong

2014-12 *Technology life cycle and specialization patterns of latecomer countries. The case of the semiconductor industry* by Giorgio Triulzi

2014-13 *Patents as quality signals? The implications for financing constraints on R&D* by Dirk Czarnitzki, Bronwyn H. Hall and Hanna Hottenrott

2014-14 *Assessment of effectiveness of Chinese aid in competence building and financing development in Sudan* by SamiaSatti Osman Mohamed Nour

2014-15 *Education, training and skill development policies in Arab Gulf countries: Macro-micro overview* by SamiaSatti Osman Mohamed Nour

2014-16 *Structure of labour market and unemployment in Sudan* by SamiaSatti Osman Mohamed Nour

2014-17 *Overview of knowledge transfer in MENA countries - The case of Egypt* by SamiaSatti Osman Mohamed Nour

2014-18 *The impact of ICT in public and private universities in Sudan*by SamiaSatti Osman Mohamed Nour

2014-19 *End-user collaboration for process innovation in services: The role of internal resources* by Mona Ashok, Rajneesh Narula and Andrea Martinez-Noya

2014-20 *Public investment and regional politics: The case of Turkey* by Mehmet Guney Celbis, Denis de Crombrugghe and Joan Muysken

2014-21 *Infrastructure and the international export performance of Turkish regions* by Mehmet Guney Celbis, Peter Nijkamp and Jacques Poot

2014-22 *Discovering and explaining work-family strategies of parents in Luxembourg* by Nevena Zhelyazkova

2014-23 *Parental leave take up and return to work of mothers in Luxembourg: An application of the model of nested dichotomies* by Nevena Zhelyazkova