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ASSESSING ECONOMIC IMPACT OF RESEARCH AND INNOVATION

Abstract: Measurements and instruments have played a crucial role in the development of natural sciences. This paper is devoted to a critical analysis of their analogues in assessing research, innovation and economic development. A variety of presently used indicators such as gross domestic product, human development index and genuine progress indicator, and similarly impact factor and Hirsch index will be discussed and possible improvements will be suggested analyzing their relevance for economic development.

INTRODUCTION

More than 100 years ago Lord Kelvin said that unless one knows how to measure and to express that result in numbers, one cannot make any reliable statement. During the 20th century measurements pervaded all studies, so that at the start of the 21st century a book was written „The First Measured Century” (1). Extensive measurements are performed and data are collected and regularly published. Frequently, it is national government responsibility to collect and publish these data. Majority of the measurements are quantitative. Kelvin would be happy. Would he? He knew that possibly the greatest philosopher who ever lived – Aristotle – failed to properly measure motion. Aristotle was an excellent experimentalist, a keen observer, whose studies in biology were remarkable. Yet, he failed to properly measure motion and his incorrect procedure to measure stopped the development of physical sciences for over thousand years, prompting Russell to castigate Aristotle as a greatest hindrance in the history of science. This story serves to emphasize that measurement is a very difficult task and that even the greatest can fail. It also shows that measurements are essential. Though universe is beautiful and to a large extent logical – as Aristotle believed and assumed – it is impossible to underestimate measurements. Success of physical and life sciences today are rooted in precise and adequate measurements connected with theoretical studies. Measurements often

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generate paradigmatic changes in our understanding of Nature and in turn these changes influence the meaning and the very process of measurements.

Social, economic and political activities pervade all human activities and therefore, they are of utmost importance. We will focus on socio-economic and political indicators. Science itself and research activity are governed by social, economic and political circumstances and therefore impact of science has to be assessed economically and politically.

What do we measure?

Large collections of data are regularly published by UN organizations, national governments and various associations. Here are just some examples: Gross domestic product (GDP), total and per capita for individual countries and/or regions. GDP can be corrected by introducing purchasing power parity (ppp). There are several additional improvements, e. g. Human Development Index (HDI) (2), which lumps together economic (GDP/capita) and some social (health through life expectancy and school enrollment) indicators. Income inequality is assessed via GINI index and/or comparing the income of 10% richest to 10% poorest population. Poverty is assessed by listing probability at birth of not surviving a specific age, and the concept is applied with different age limits to developing and advanced economies (2). Additional improvements of economic indicators are Index of sustainable economic welfare (ISEW), Genuine Progress Indicator (GPI) and Calvert-Henderson indicator. Sometimes, some of these indicators show different time dependence, e. g. comparison between GDP/c and GPI/c expressed in US\$ fixed at year 2000 for the USA from 1950 to 2004 (see Table I).

Table 1. Comparison between GDP/c and GPI/c for the USA

Year	1950	1970	1990	2004
GDP/c	11,672	18,773	28,434	36,595
GPI/c	8,611	13,034	14,893	15,035

Absolute magnitude and even more importantly time dependence of GDP/c and GPI/c are very different.

Even this non-exhaustive list of economic indicators shows that something is wrong. Why so many? Which one is the best? Kuznets, who introduced GDP in 30 ties stressed that GDP is not the measure for welfare. The same point was emphasized by Tobin and by the first Nobel laureate in economics Jan Tinbergen half a century ago. A simple example proving it is that GDP of the state of Louisiana increased after the hurricane Katrina. In one of his last speeches Senator R. F. Kennedy said „We will find neither national purpose nor personal satisfaction in an endless amassing of worldly goods. We cannot measure national achievements by GDP, since GDP includes air pollution, cigarette advertisement and ambulances to clear our highways after carnage. It counts special locks for our doors and jails for people who break them. GDP includes destruction of redwoods and of Lake Superior. GDP grows with the production of napalm and nuclear warheads. It does not in-

clude the health of our families, the quality of their education, it is indifferent to the safety of our streets... In short, GDP measures everything except what makes life worthwhile." Everybody is aware of shortcomings of GDP and GDP/c and this prompted the European Parliament to organize studies culminating in a conference with The Club of Rome entitled *Beyond GDP*. President N. Sarkozy invited a group of experts to formulate adequate economic indicators.

Realizing that economic activity is not an adequate indicator, an attempt was made to assess welfare and well-being and several indicators measuring human happiness were introduced (3). Recently University of Leicester published a world map of happiness and Denmark, Switzerland, Austria, Iceland, Bahamas, Sweden, Finland and Butan top the list. The USA is 23rd and Croatia is 98th (4). Friends of the Earth published the happy planet index which includes the ecological footprint (5). The ranking changes appreciably: Austria is ahead of Denmark, and Croatia is considerably ahead of the USA due to a very large ecological footprint of the USA.

Recently economic activity has been assessed using global competitiveness index and economic freedom of the world index (EFW) (6). EFW is assessed through 42 indicators in five spheres: government expenditure, legal structure and property rights, access to capital, freedom of international trade and regulation of credit, labor and business activities. Based on these indicators a composite index in the range of 0–1 is calculated. In 2006 Hong Kong got the highest value (8.94) and Zimbabwe the lowest (2.67). Environment-economic activity relationship has been assessed through Environmental Sustainability Index (ESI) and similar indicators (7). All these indicators are aggregates of a large number of various input indicators.

In the 20th century research activity grew in number of researchers and in the nominal percentage of GDP allocated to research and development (R&D), the so called gross national expenditure for R&D (GNERD). Two standard indicators used are the number of researchers and GNERD. Both of them are inadequate. The number of researchers includes also those who are not scientifically active. GNERD includes salaries for non-R&D/education personnel and activities that are not R&D/education. It is argued that these are input indicators and that the output indicators represent a better measure. Output R&D indicators, e. g., number of publications per researcher and impact factors are more reliable (8). The H-factor, number of publications cited more than H times, has been introduced to assess scientific elite (9). Scientometrics data should be used with care, e. g. impact factors vary significantly from one to another scientific discipline. Even a peer review has been criticized providing evidence that sometimes peer review is not much better than a random choice (10). Scientometrics indicators are statistical indicators: instructive when assessing a country, but not when assessing individuals or small group. Therefore, scientific impact of nations can be measured (11), but comparing Einstein and some Nobel laureates through scientometrics indicators is pointless. Impact factor and H-index are not quite good even when assessing countries, since even in large countries there could be very few scientists and not in all disciplines so the comparison between a country with a full spectrum of scientific activity and another one of equal population and/or equal GDP, but with grossly different scientific-technological potential, is inade-

quate. It is still an open question whether in assessing research-innovation interaction is better to assess the entire scientific-technological potential or just its peaks.

There are a very large number of political indicators, e. g. Globalization Index (12) and scores for achieving democratic and economic reforms (13). Democratization Score is an average of a political process, civil society activities, a degree of independence of media and governance and public administration ratings. Rule of Law Score includes constitutional, legislative and judicial framework and corruption ratings. Economic liberalization score assesses success in privatization, macroeconomic and microeconomic policy ratings. Rating and scores are based on a scale of 1 to 7 with 1 representing the highest level.

Most of these indicators are measured regularly, some yearly. Time dependence of some of these indicators has profound political implications, e. g. GDP/c growth or decline and Global competitiveness index increase or decrease. Index of economic freedom for e. g. Bulgaria increased from 5.35 in 1990 to 6.36 in 1995 and to 7.41 in 2000. For Albania it increased from 5.99 in 1995 to 6.58 in 2000, while the world average was 5.68 in 1990 and 6.58 in 2000. For most of the countries of the world index of economic freedom increased in the last two decades. On the other hand GINI index of inequality is typically increasing, i. e. the inequality is increasing. Data on inequality for some former socialist countries are summarized in Table 2.

Table 2. Gini Index for comparative per capita consumption (14)

Country	1987-1990	2001
Bulgaria	0.245	0.351
Estonia	0.240	0.402
Hungary	0.214	0.268
Poland	0.255	0.356
Slovakia	0.186	0.299

The subject of inequalities is very large and we restrict here only to list some references (15, 16).

According to the Freedom in the World study there were in 2002 89 free countries with a total population of 2.5 billions, 56 partly free with total population of 1.49 billions and 47 not free with total population of 2.49 billions, compared with assessments in 1972 when there were 43 free, 38 partly free and 69 not free countries, while in 1893 only New Zealand could be considered a true democracy (13). Recently the concept of failed states has been introduced (17). Somalia, Chad, Sudan and Zimbabwe top the list closely followed by DR Congo, Afghanistan, Iraq and Pakistan. Peace Index (18), developed by the University of Sydney group and by the Economist team based on 24 input indicators puts Norway, Denmark and Japan at the top of the list. France is ranked 36th and Vietnam 37th, UK 49th, Croatia 60th, Turkey 92nd, the USA 97th, India 107th, Pakistan 127th, Russia 131st and North Korea 133rd – all nuclear powers are ranked very low and famous old dictum „prepare for war to enjoy peace is clearly incorrect”.

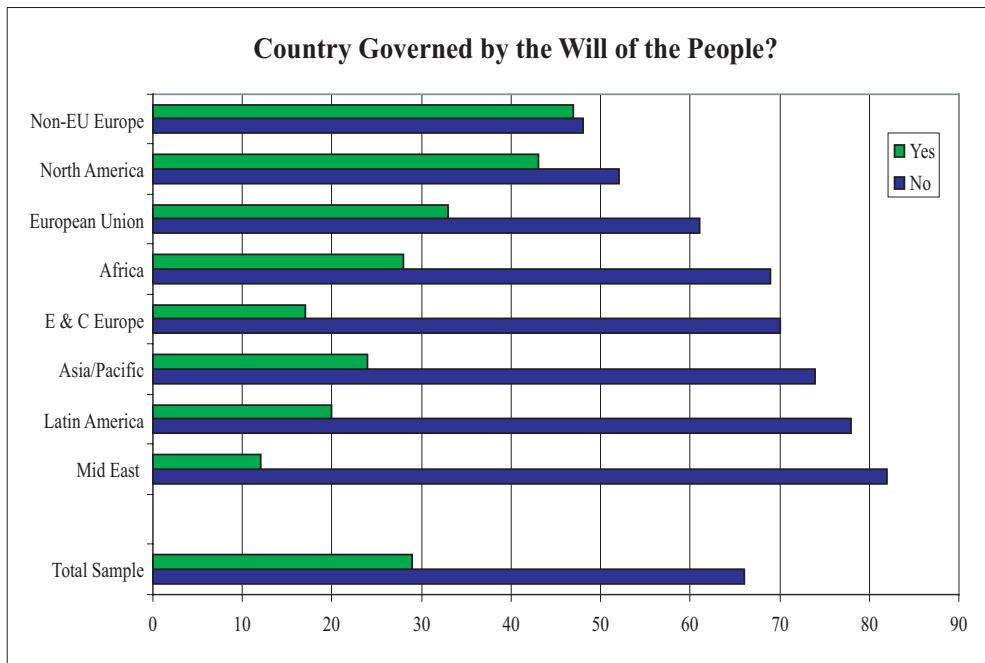


Fig 1.

How reliable are our measurements and do they help to achieve socio-economic and political actions we desire? It seems that the answer to both questions is negative. Inadequacy and non-reliability of our economic indicators is possibly best demonstrated by the fact that no indicator even suggested and much less foresaw any of financial and economic crises since 1950 ties. Some measures recommended to countries facing economic problems by the World Bank (WB) and by International Monetary Fund (IMF) turned out to be more often wrong than correct measures. Most of the current recommended policies suggest increasing spending thereby leading to increase in GDP, but interconnectedness between economy and ecology is entirely ignored. Are road and skyscraper building, albeit increasing GDP, activities that would not lead to more destruction of our environment? Can our planet tolerate higher production and consumption of fossil fuel, though that would lead to increase in GDP? How do we cope with the fact that the world will need in 2050 almost three times more energy production that it has today (19)? Economic indicators that include social indicators and welfare, e. g. HDI, ISEW, GPI or a number of happiness indicators are too complex and data can be provided with a considerable time delay to be able to serve for practical political and/or economic actions.

Political indicators are even less reliable as it is best demonstrated by several opinion polls. Gallup International's 2002 Voice of the People survey (20) of 50,000 citizens across 65 countries on six continents provided therefore, results statistically representative of the views of 1.5 billion citizens showed that only 7% of the respondents

GOVERNED BY THE WILL OF THE PEOPLE					
			Yes	No	
		Pillars of democracy	Disillusioned		
ELECTIONS	Yes	world	26%	23%	
		E&CE	20%	16%	
		N. America	32%	24%	
	No	Outsiders		Malcontents	
		world	6%	45%	
		E&CE	4%	61%	
			N. America	7%	38%

Fig. 2

strongly agree with the statement that the world is going in the right direction, and additional 23% somewhat agree with that statement, a mere 30% to be compared with 36% in the year 2001. Almost 70% state that their country is not governed by the will of the people. Fig 1 shows responses for various regions. In some regions: Mid-East and Latin America that percentage is around 80%. This indicator together with information whether the elec-

tion have been held and whether they are free is combined into a political stability index (PSI) being defined as a difference between the percentage of those citizens who believe that the elections in their country is free and those who are malcontent and believe that their country has no free election and is not governed by the will of the people (Fig 2). From 2003 to 2005 PSI decreases and it becomes even negative.

It could be argued that concepts of democracy and of governing by the will of the people are not well identified and/or understood by everybody in a same way. This can be partly substantiated by data on values: freedom vs. order (Table 3), and egalitarian preference (Table 4).

Table 3. Freedom vs. Order (15)

Country	Preference for freedom	Preference for order
(% of respondents)		
Poland	19.8	66.3
Czech Republic	21.4	72.4
Sweden	48.1	42.5
USA	48.9	46.2
World	40.9	54.0

Table 4. (15)

Country	Egalitarian preference	Against egal. pref.	Government act.
Hungary	78	17	1.66
France	61	34	1.91
Sweden	54	40	2.27
Netherlands	45	52	2.52

Government action: the following question was asked: Government should take measure to reduce differences in income: 1. Agree strongly, 2. Agree, 3. Neutral, 4. Disagree, 5. Strongly disagree.

ESSENTIAL CONDITIONS TO BE SATISFIED BY INDICATORS

A useful indicator should be well defined so that its correct measurement is assured. Since most of indicators are provided by national governments and in the global era it is advantageous for governments if indicators have values in a desired direction, the objectivity of governments in providing proper information is questionable, as demonstrated by economic data that are at least partly to be blamed for recent euro problems. Even worse, governments can perform political actions that would produce a mirage of desired results, e. g. if the government changes the laws to artificially increase the number of educated person or decrease the illiteracy rate. Therefore, more than one indicator is often needed to check the reliability of each indicator.

Indicator should be such that the data are promptly available. Indicators do serve policy actions and delays longer than half a year make data irrelevant.

Indicators have to be robust and with as small uncertainty as possible.

Indicators measure input and output information and typically those that measure output are more reliable. However, these output data are obtained a posteriori, and thereby can be less useful in guiding policies and decisions.

It is impossible to express everything by numbers, so in addition to quantitative indicators, there is need for qualitative indicators.

METHODOLOGY FOR DEFINING AND SELECTING INDICATORS

The essential question is what are indicators used for? What do we want to accomplish by using indicators? At present we measure as much as we can measure. Is this enormous amount of information useful? Would Aristotle understand motion better, if he would have measured shape, color and composition of falling objects. Some of these data would be useful, but many would be useless and redundant. Though Aristotle believed in logic and beauty, he was missing a necessary theoretical basis, he did not have the foundation for the underlying conceptual theory. We have already pointed out that many of concepts that we are „measuring” are not precisely defined and in particular, since the measurements are done by different persons having different concepts, perceptions and even influenced by their preconceived ideas, we rarely have a consistent set of data. Our task is to proceed simultaneously developing a theory/theories and collecting data thereby developing our understanding of socio-economic and political processes.

A CALL FOR PROPOSALS

Indicators reflect the conceptual basis underlying the approach to the problem. Physicists of the 16th century and on tried to understand motion and interactions

and that led to measuring time, distances and masses. They tried to relate changes in the position during a given time interval caused by interactions. These well-defined and objective measurements are the foundations of physics. The concept of development is much more complex. There is confusion/mixture between concepts of development and growth.

Growth is the quantitative increase in the physical scale of the economy, in throughput of matter and energy, and the stock of human built artifacts. Development refers to mainly qualitative improvements in the structure, design and composition of physical stocks and flows that result from greater knowledge, both of technique and of purpose. A sustainable economic system is focused on development, not on growth. Development involves economical, sociological and political activities of human beings, living in the environment determined by the laws of natural – physical and life – sciences. Human activities are rational and irrational, based on values, on culture including prejudices, containing historical information and characterized by sudden changes, some rational and some irrational (21, 22).

The Genuine Progress Indicator (GPI), Index of Sustainable Economic Welfare (ISEW) and Calvert-Henderson (C-H) indicators attempt to measure interactions between economy and environment, thereby are sometimes labeled as green GDP. GPI's structure is based on principles set forth in Natural Step, Hannover Coalition for Environmentally Responsible economics (CERES) and similar frameworks that call for no net loss of natural capital, for distributional equity and throughput minimization. All and each one of these indicators is superior to GDP, but nevertheless, GDP and GDP/capita persist as the main indicator used by politicians and by media, influencing the public. GDP was developed and used to find untapped resources to help the nation (e. g. the USA) to recover and to win the war (23). GDP is primarily a policy-motivated (even a political-motivated) indicator. GDP is now used by economists, policy- and decision-makers, international agencies and media as the primary scorecard of nation's economic health and well-being. Yet, as we know from its creator Simon Kuznets (24) GDP was never intended for that role. The GDP is simply a gross tally of everything produced – products and services, good things and bad. M. Max-Neff pointed out that over time more and more economic activity is self-canceling from a welfare perspective. For every society there seems to be a period in which economic growth brings an improvement in the quality of life, but only up to the point – the threshold – beyond which, if there is more economic growth, quality of life may begin to deteriorate (25). Abrupt difference between GDP and several other indicators, as e. g. happiness / life satisfaction and energy consumption are similar manifestation of Max-Neff effect. Historical analyses could prove (and most likely will prove!) that GDP *was* a very good indicator to achieve its political and economic objectives and the economic growth from 1930 to 1970, but today, GDP leads to wrong decisions: destruction of the environment, missed opportunities and misuse of human capital. Nevertheless, many argue that GDP is correlated with several important socioeconomic indicators, e. g. there is a linear correlation between GDP/capita and Personal well-being of EU member states (2009 Report). Correlations do not and cannot prove that any indicator is re-

liable and that policies and decisions based on that indicator are not wrong. GPI and ISEW as well as International Index of Social Progress (IISP) (26) drastically differ from GDP, e. g. the USA is ranked second according to GDP/capita in the world and 27th according to IISP.

Why is an inferior indicator still used while better indicators are available, but not used? Albeit better, GPI, ISEW and C-H have at least two shortcomings. First, they are complicated and value-determined and therefore subject to gross manipulation of those who provide information, primarily national governments. Second, since they contain additive (and subtractive) terms, cancellations can occur, and the negative aspect of some policies can be temporarily compensated by other effects, but some of these policies and decisions could have bad effects later on. Currently, GPI data from 1950 exist for the USA and for Australia, and ISEW data for Austria, Chile, Germany, Italy, the Netherlands, Scotland, Sweden and the UK. This lack of data is also indicative. Nevertheless, it has to be pointed out that there are attempts to use GPI as a guide to policy (in Bay area, in Alberta and in Nova Scotia).

The success of GDP was at the beginning due to the fact that it was a very convenient indicator for monitoring the achievements of the national political and economic goals: recovery and winning the war. Let us attempt to formulate not the „scientifically best” indicator, but again an indicator that would facilitate the achievements of our goals.

The contemporary world is facing economic, social, environmental, political and moral crises superimposed on climate change, increasing energy demands and demographic transition, plagued by continuing violence, war and terrorism. During last decades we witness significant destructions of natural, social and human capitals, superimposed on the self-augmenting process of both social and human capitals. At the same time, this is the best of time: last two hundred years have witnessed several major scientific breakthroughs in physical, life, cognitive and information sciences. Peter Drucker coined the concept knowledge-based society and European Union declared as its goal to become the knowledge-based sustainable society by 2020. Though intuitively acceptable, the idea of knowledge-based sustainable society and particularly the process of achieving it, still needs clarification.

We argue that we imperatively need to quickly stop the destructions of natural, social and human capital. We need paradigmatic changes and we need indicators to measure these changes. These indicators have to be sensitive, directional – to achieve specific policies and with short time response, i. e. effects of individual, specific political, economic and social measures should be rather promptly reflected by indicators uniquely linking the measure with the effect. This is a very tall order. It is very difficult since most of the causes and effects are interwoven and interconnected. Various examples of wrong political, economic and social measures can be listed, e. g. wars, military interventions, armaments, particularly nuclear armament, continuous consumption of fossil fuels, destruction of trust through various profit stimulating measures, such as deregulations, reduction, restriction as well as inadequate and wrong healthcare and education. Goals to increase employment rate without clearly distinguishing non-desirable employment such as mil-

itary and any employment involving natural capital destructions (e. g. not-needed road building, excessive car manufacture), as well as redundant bureaucracy (but how to distinguish redundant bureaucracy from necessary service economy is again a difficult task) vs. desirable employment such as research, education, innovations, healthcare and food and needed merchandise production. We reiterate: we urgently need good measures of changes. Political process filtering out unfulfilled promises is not a clear and adequate indicator.

We start with four basic capitals: human, social, natural and physical (economic, infrastructure). Human capital is responsible for increasing (and destroying) all other capitals (27, 28, and references therein). Human beings are our greatest wealth – „People are the real wealth of nations. The basic aim of development is to enlarge human freedom and choices so that people live full and creative lives. This must *benefit everybody equitably*.”(29) Human capital is inexhaustible and self-augmenting. Many indicators provide some assessment of the human capital, e. g. life expectancy and under-five-mortality, percentage of healthcare allocations in the total GDP, number of hospitals, physicians and nurses per million population, average years of schooling and percentage of those enrolled in organized lifelong education with respect to the specific age group cohort, percentage of all educational allocations in the total GDP, skilled personnel shortages indicating inadequacies of the educational system, and mobility of the workforce, particularly return to home country measuring to what extent the system is global and integrated, employment rate, unemployment of specific age groups, employment in various activities, (large part of work is non-monetized, e. g. parenting, elder persons and sick persons care, housework, volunteer work, and even non-monetizable -i. e. it cannot be replaced/substituted by the activities of other persons who would be paid for that work, e. g. self-„improvement”, i. e. to be a better member of our contemporary world. Following the methodology outlined in section 3. it is necessary to select just some indicators within this huge range. It is particularly important to emphasize the connection between the human capital and all other capitals. Almost in general it is human creativity that leads to increases in other capitals, e. g. humans developed the way how to use iron, oil, uranium, humans invented road, airplanes, internet to strengthen social networking, as well as social structures: cities, states and the global world, and of course, humans created all economic wealth. Measuring human capital, even a simpler task assessing the gradual process of achieving the EU goal of the knowledge-based society is extremely difficult.

We have undertaken a simpler task of formulating indicators of economic progress (30) and in Fig. 3. We display the comparison between our proposed indicator HEWI and GDP. We aimed for satisfying methodological conditions outlined in section 3., i. e. simplicity (we subtract of GDP contributions due to activities destroying natural capital and to military activity. We tried to subtract useless administration), we correct GDP for inequality and use the procedure similar to that of A. Sen. We emphasize the importance of employment and tried to assess the changes caused by country's activity (we succeeded only partly) and we tried to assess the effect of education on human capital. We are fully aware that we are not

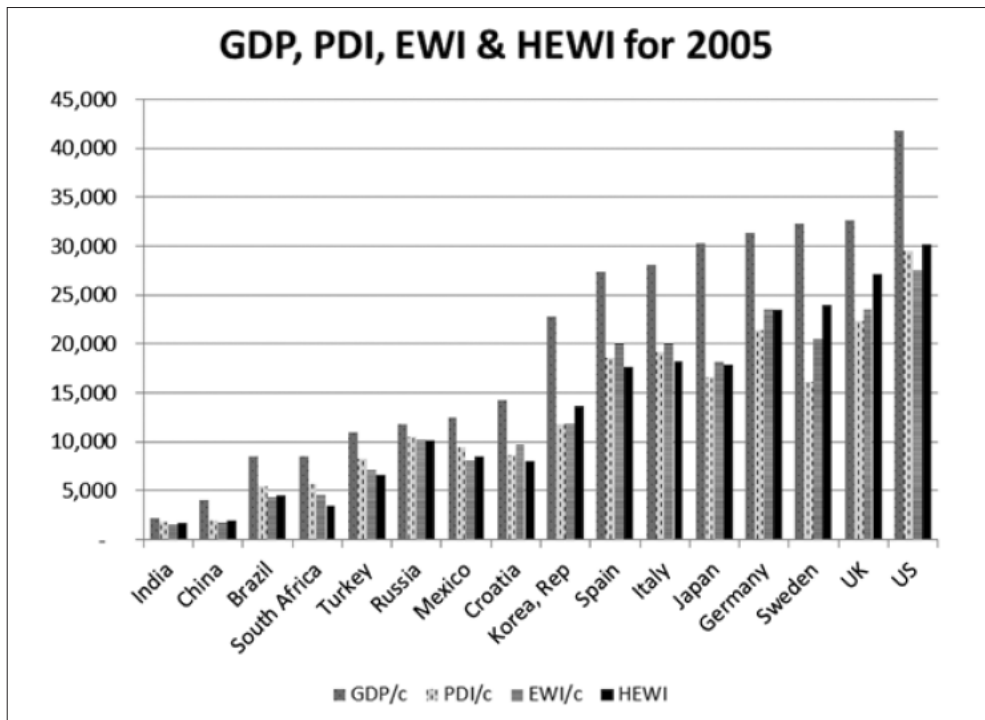


Fig 3.

even close to have any measure of the process of achieving knowledge-based society. We assess the interconnection between humans and natural capital by measuring fossil fuel efficiency. This is one of our weakest assessments. Fully aware of all shortcomings of our work we argue that HEWI is a reasonably good policy and decision-making indicator and that its components can be used independently to measure the effect of specific decision-making.

PDI represents personal disposable income which is directly available to individuals after taxes. EWI takes into account PDI, corrects it by adding government welfare expenditure on households and for inequality by multiplying with: $(1.1 - 0.65 \text{ GINI})$: We argue that complete equality is neither desirable from economic productivity standpoint nor humanly possible. HEWI is a product of four terms: EWI, energy efficiency (restricting to fossil fuel), combined education enrollment and employment index. HEWI can be used either as a combined indicator, or each individual term can be used to assess effects of specific policies and decisions, e. g. employment index to measure whether a specific policy leads to employment increase. It is interesting to point out that Keynes used employment data, since at that time GDP was not yet introduced.

I often heard that physicists recently massively entered the field of economics. It was not only the first Nobel laureate J. Tinbergen, but many more and quite recent-

ly. Did they spoil the field? They brought with themselves their excellent knowledge of modeling, of computing and of mathematics, but they forgot to take with themselves the essential quality of physics research: questioning all underlying assumptions, questioning all sacred cows. Indicators and measurements are just one segment of the economic system. How about sacred cows in our contemporary economy: money, private property and market mechanism? All capitals are measured in money, and money is not a good measure for either human or social capital and barely so for natural capital. In addition, money behaves as a bubble. While world GDP/year amounts to about 40 trillion Euros, a considerably larger amount is moved through world markets yearly, i. e. 2-4 trillions/day bringing the yearly amount to about 1,000 trillion, i. e. virtual overwhelms real by a factor of about 20-30! One sacred cow of the current economic theory – money is obviously in trouble. Problems with money were encountered before, e. g. in the 17th century when gold coins were decreasing in size. As coins were circulated people chipped off parts and kept that chopped-off gold for themselves. Isaac Newton, at that time the head of the English Mint, solved the problem by marking the edges of each coin. We do need an innovative solution now as well. Money is related to another major contemporary problem: organized international crime (31). In his interview to Italian newspaper Repubblica a former CIA chairman said that off-shore banks like those on Cayman Island and even in major world capitals should be proper targets to eliminate international terrorism. However, money and banking are among the greatest technologies humankind developed. Without money and banking there would be no great economic progress humankind has achieved. The other sacred cow is private property, since obviously in the global world commons are essential. Air should be considered such a global common good as well as Antarctic, oceans and fresh water. The concept of sovereign national borders could be in trouble. However, experiments with no private property all failed and resulted in economic disasters. Finally, the most sacred of cows – the market economy, often called the free market economy, but in reality markets are only partly free and often governments interfere, as witnessed now during the crisis of 2007-9. In at least three cases market mechanism failed. First, global climate change, as argued by Nicholas Stern in his famous Report, can be overcome now with few percents of GDP, but would require 20-30% of GDP if one delays the action. Second, real estate bubbles – where people lived in houses the value of which first increased by a factor of 2-3, and then abruptly fell by a factor of 5-8, and they were all the time in the same house, and they would feel the effect if and when they would sell the house, and they lost their houses because they were unable to pay the mortgages. The third failure is employment – possibly the most serious failure. However, we are aware of the importance of all these sacred cows and we have evidence that they are indeed „sacred” in some domains. Taking the analogy from physics, one could say that all these concepts: money, private property and market mechanism are excellent concept in their domain of validity just is Newtonian physics is excellent for low velocity and when the disturbance in the process of measurement is negligible. If one accepts such a view, it is important to define these domains, and we are nowhere close to that. Bounda-

ries are difficult to be drawn. For instance, it seems plausible that healthcare should be guaranteed, and the usefulness of private practice can be questioned. However, there is ample evidence that fully socialized medicine is catastrophic.

Taxes are the connection between the economic and social spheres. It is well known that taxes are paramount political issues. Taxes could be used to stimulate certain policies. For instance, the uses of all renewable energies could be declared as tax-free and similarly workforce for production, healthcare, education and research could be also declared tax-free, thereby making labor much cheaper than it is in some countries, and making difference between these types of work and so called „non-productive activities” as administration, military and police. Of course, currently the largest fraction of government’s income comes from taxes on labor.

We have emphasized that human capital is the most important capital and yet none of three sacred cows we have addressed: money, private property and market mechanism adequately and completely assess and treat human capital. Human capital, as we have said, is inexhaustible, it increases by sharing, it depends and it influences all other capitals and it is self-augmenting. The development of human capital over time is a function of the quantity and quality of human capital. We label human capital including all forms of social capital by Ψ , natural capital (e. g. ecosystem, air, water) we denote by Φ_N and human-made capital (e. g. money, infrastructure, building, roads) by Φ_{hm} . Though resources exist outside and independent of human beings, they are recognized as resources only by human beings. Knowledge is a resource that exists only within human beings. Human capital, natural and human-made capitals are interconnected. This relationship can be expressed mathematically. Improving healthcare, education and employment augments human capital in a way that is proportional to the human capital ($\lambda\Psi$). Equally, improving socio-economic and political conditions and facilitating and stimulation creativity augment human capital even more than proportionally ($\mu\Psi^a$). Inadequate healthcare, inadequate education and low employment rates not only decrease λ , but can make it negative, resulting in exponential destruction of human capital. Similarly socio-economic and political conditions can have beneficial and destructive effects.

In addition there are sudden changes, black swans, which we labeled P for those having positive and D for those having destructive effects. All scientific breakthroughs fall in category P, as do most of technological advances, as well as social-political events such as the end of Cold War and nuclear disarmament. War, any form of violence, injustice, large income inequalities, violation of human rights and terrorism destroy human capital. Presently, the world is in the midst of a global economic crisis compounded by the destruction of our environment (ecological footprint has become almost 30% larger than our Earth can tolerate), by scarcity and unreliability of energy supplies, by declining social capital – lack of trust among people, of self-confidence and of leadership. These crises are interconnected and interdependent. Each one of these crises and totality of all of them destroy hu-

man capital. All of them are represented by a function D . Nuclear war and climate change can lead to catastrophes or even to an end of civilization.

Human capital, natural and human-made capitals are interconnected. This relationship can be expressed mathematically by eqn (1):

$$d\Psi/dt = \lambda\Psi + \mu\Psi^a + P - D + \alpha (d\Phi_N/dt)\Psi + \beta (d\Phi_{hm}/dt)\Psi + \gamma (\Psi, \Phi_N, \Phi_{hm}) \quad (1)$$

The interdependence among various forms of capital is represented by the last three terms in equation (1). The term $\alpha (d\Phi_N/dt)\Psi$ demonstrates that human capital decreases if natural capital decreases, i. e. if $(d\Psi/dt)$ has a large negative value. The term $\beta (d\Phi_{hm}/dt)\Psi$ shows that human capital also decreases if human-made capital decreases, e. g. as a result of destructive human activity such as war. The complex interdependence of all forms of capital is shown by the last term $\gamma (\Psi, \Phi_N, \Phi_{hm})$. λ , μ , P , D , α , β and γ are time dependent.

It is even more complex. Entities are not clearly specified. For instance, a human being of the 21 th century is simultaneously exploited and exploiter, producer and consumer, global and local, and there is no analogue of quantum physics to reliably calculate probabilities when we are exploited and when we are the exploiter. Obviously, we are just at the beginning of the new economic theory.

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