On Measurements of Green Economy: Sustainable Economic Growth, Steady State and Social Discount Rate

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Abstract: This article analyses green economics as an alternative doctrine to the concept of economic growth in the theory of traditional economics. The article will bring basic existing theoretical views on both directions and consider how consistent or divergent they are. As a measure of population well-being and economic growth, it is indicated that the results differ depending on what exact units are selected. The social discount method was used as the main methodology. To measure the green economy quantitatively and qualitatively, a conclusion is made according to the results that are characteristic through the analysis of statistical indicators, which are directly and indirectly related.

1 INTRODUCTION

Beginning from the 20th century the whole world observed a high rate of economic growth due to the industrialization process. In this period the living standard of the world population rises, inducing higher aggregate demand on consumption by the multiplicator effect. This in turn motivated global industries to produce even more.

At the beginning of this process, even though there were concerns about the scarcity of natural resources, the problem of climate change didn't seem to be crucial. Synthetic materials began to compensate for the lack of natural resources. However, a sharp increase in population, the separation of the business world from residential areas into separate industrial zones, in general, the level of urbanization began to affect the Earth's ecosystem. Industrial waste and its environmental damage have reached the agenda.

This trend brought the views on economic growth, and the optimality of the market economy into question by activists of various eco-movements, who put forward the fact that market failure might arise affecting the natural climate. The degree of these different orientations varies from neutrality to absolute antigrowth view. The concept of a "green economy" thus arises, which in many cases is presented as an alternative doctrine to traditional industrial economics. And our task is to give a theoretical and practical assessment of these views.

Steady state is such a level of the economy in which the accumulation of capital is slower than its depreciation, and ultimately the economic growth stops. In such economies, wages are high and investments will pay off only after being focused on some new directions. For instance, the transition to a green economy can also be achieved by increasing human capital.

A social discount rate is a way of adjusting nominal units to real values. It can represent different

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values such as utility, consumption, interest rates, and goodwill. Hence, the social discount can also be applied appropriately in the green economy measurements. In this article, we aim to bring as many abstract concepts as possible to an alternative real value through a social discount rate.

2 THE MAIN RESULTS AND FINDINGS

In the study of the measures of green economy, we use the concepts of steady-state and social discount, the main concepts of economic growth, with the aim of clarifying its view as sustainable economic growth and simultaneously as an antigrowth direction.

To begin with, we consider a modification of the Neoclassical model, in which other than two main factors of production such as Human capital and Natural resources, its transition to the steady state and the possibility of transformation to a green economy in the steady state. We assumed that the process of transition to a green economy would be through a change in the relative efficiency of production factors.

We also apply a social discount rate to adjust the value of the traditional economic indicator that ensures the well-being of the population. We have tried to use continuous functions such as those used in modern works on the subject of economic growth and the representation of social discount rates. Continuity is becoming a more convenient method than discrete timing, not only in theoretical accuracy but also in empirics.

We tried to select variables that represent the constructive and destructive effect on the green economy to estimate those put in identities: they are the Global Green Economic Index and greenhouse emissions. In the regression analysis, we used cross-sectional data. We found it necessary to express them temporarily implicitly, referring to the possibility of being biased in the coefficients because of few samples and the fact that their quantitative and qualitative increase is a matter of time, as well as the fact that both regressions are one-factor.

The works of Molly Scott Cato (Cato, 2012), Nicholas Stern and William Nordhaus are known directly on the green economy (Stern, 2006). Economic growth and at the same time research on the green economy can be found in the works of Daron Acemoglu (Acemoglu, 2009), Barro (Barro, 1995) and Christian Groth (Groth, 2014). They have modified the models introduced by Robert Solow (Solow, 2011), Malthus and Kremer (Kremer, 1993). Also, the approach to Social Discount, presented in the Arrow (Arrow, 2009) and Sterner (Sterner, 2008) studies, can be used as a methodology for measuring the green economy.

While green economics is a relatively new economic concept, it relies in many cases on existing traditional economics theory.

At a microeconomic level, the green economy questions the dichotomy that the market is optimal and its participants are rational. The "invisible hand" can bring the manufacturer and consumer into balance, who are seeking to maximize profits and utility in a particular market of goods and services. However, no one guarantees that both parties, which are in the concern of maximizing their own interests, will be concerned about the environment. The manufacturer, although not eco-friendly, uses production factors as cheaply as possible, and the consumer also seeks only marginal utility. This is where externalities come from.

Social compensation of externalities, on the other hand, in this case, by levying environmental taxes, reduces the incentives of manufacturers. In practice, the burden of excise and other indirect taxes is also known to be imposed on the consumer. As a result, demand is less than balanced, and allocative and productive efficiency is not achieved. Society's gross welfare decreases.

At the same time, proponents of the green economy argue that the above discussions, especially market optimization and efficiency, are very abstract concepts. In this context, they can be said to agree with behavioural economics. According to Behavioural economics, consumers are not rational in decision-making. They are closer to the nature of Homo sapiens than Homo economics. Therefore, tools such as price and the invisible hand of the market cannot guarantee social well-being even in perfect competition. And in the mixed case of real markets with monopolies and oligopolies, the likelihood of this is even less.

In its essence, the green economy suggests that there will be as many natural areas as possible, including forests, enclosures for animals, and as low as possible industrial and household waste, even in densely populated areas. And in practice, this can only happen with the expansion of social properties. Private property and businesses, on the other hand, will have to adhere to regulatory norms. As you can see, this contradicts a pure market model.

The Coase theorem offers an optimal solution to this dilemma. Positive externalities are subsidized and negative externalities are subject to taxes and

fines. This principle also has a direct connection to the green economy. For example, ensuring that the plant world is pollinated can be done in a regulatory way, in addition to the processes that take place through natural ventilation. Honey producers need to be encouraged through subsidies to areas where the plant world needs to expand.

The manifestations of the theory of the green economy criticize the priority of constant economic growth. That is, the well-being of the population should not be measured by constant economic growth. Therefore, the antigrowth position is distinguished.

Indeed, even according to economics, human needs increase endlessly, as reflected in the Maslow model. Of course, even in a green economy, human needs are supported as much as possible. However, this must be based on natural quality. The well-being of the population, on the other hand, can be ensured only by optimally and wisely allocation of limited natural resources.

The above problem can be analysed through existing models based on population growth and a limited resource paradigm. The main ones are the Malthus and Kremer models. These include alternative models.

According to the Malthus model, the population will grow steadily, and hence proportionately their needs. Because of the limitations of natural resources, especially crops, per capita resources decrease and the level of well-being of the population decreases. Economic growth is not the only solution, which contributes to a further increase in needs in such a condition. Indeed, until recent history, the plant world was considered a key source not only for food but also for energy. For example, in the warming and processing industry, wood has been used primarily as fuel. If alternative coal, gas, oil and other fuels were not discovered, it was inevitable to expect forest areas to decline dramatically.

According to Kremer's model, on the contrary, the population's well-being increases as the world population increases. More innovative ideas will emerge among the larger population, and this in turn will allow a more effective distribution of resources. Indeed, the "green revolution" of the 20th century has repeatedly increased agricultural production per capita. The quality of new technologies is expanding the eligibility period for these products, the quality of which used to break down rapidly. New generations of logistics made it easier to maintain and transport them. That is, the efficiency associated with time and distance is also increasing. The use of alternative methods, such as wind in energy, synthetic materials in textiles, and chemistry in pharmaceuticals, was also unexpected in the Malthus era.

In general, the conversion of resources without processing and ineffective waste is typical of a period and space where the population is infrequent. Looking for opportunities to recycle and distribute them more efficiently is typical of more populated areas. This thesis can also be observed by comparing it in the cross-section of historical times and countries. For example, by comparing Japan with relatively low per capita resources and developing countries with increased per capita resources.

According to the Solow model, the Steady state is such a state of the economy that the efficiency of capital per capita stabilizes. It can be assumed that it is at this stage the possibilities of the green economy implication are more likely. If per capita capital is lower than this level, investment increases will keep the economy growing, and meanwhile, the relative costs of the green economy will be greater. When the capital savings per capita are above this level, investments will not be able to provide economic growth, and it will be more effective to direct them to the green economy.

In the Solow model, the next issue beyond steady state is that it is required to find such a point in the capital accumulation, where the optimal level of gross consumption of the population is achieved. GDP will be produced in the most appropriate amount for the welfare of the population, even if it is less than a Steady state. In particular, industrial and household waste to the environment will be at the minimum level.

In the case of endogenous models, which are alternatives to the Solow model, however, economic growth can be constant, and in this case, it is necessary to abandon permanent economic growth in order to advance the green economy, as some green economists have criticized.

For the golden medium, it is necessary to establish a coordinated mixture of the above existing models. This model should be modified so that it fits as much as possible into the reality, so that it can be put into practice not only within the academic framework, but also when putting the green economy on the agenda.

We now formulate the above considerations through identities in order to apply them to quantitative and qualitative measurement of green economics and economic growth, and to lay the foundation for estimating by regressional method.

Let the expression of gross produced products in the economy through production factors be as follows in traditional works:

$$GDP=A*F(K,L,N,H) \quad (1)$$

Where GDP is the gross domestic product, A is the level of technology, F is the production function, K is the amount of physical capital, L is the number of hours of labour worked, H is human capital, and N is the natural resource units.

We assume that the Constant return to scale and Inada conditions hold, as in economic growth models and in many cases empirically approved works. In this case, the productivity of each factor increases infinitely in its scarcity and, on the contrary, decreases when it increases. Including this for the productivity of natural resources we can formulate sa follows

$$(\lim)_{\top}(N\to\infty)\,(\partial F/\partial N)=0 \quad \text{and} \quad (\lim)_{\top}(N\to 0)\,(\partial F/\partial N)=\infty \tag{2}$$

The population increases and natural resources are spontaneously reproduced along with time. Depending on their reproduction rate, per capita natural resources (N/L) either decrease or increase.

According to the Malthus model, N/L should decrease as the population grows, as consumption increases. According to Kremer, on the contrary, this ratio increases because the technological level in (1) A in the equation, increases the substitutes of N its efficiency. It is evident from identity (1) that in order for N/L to increase, A and H must be as much as possible.

Under the conditions of modern stock markets, where the spot rates are changing every second in a continuous time horizon and under the conditions of variable interest rates in a given period, the intertemporal relation in which the social discount rate is considered can be written as follows

$$PV=\int_0^T \left[\left[FVe\right]\right]^{\left(-\int^t r(\tau)d\tau\right)}\,dt\Big] \tag{3}$$

Where PV is the investment value at the beginning of the period; FV is the value planned to be reached at the end of the period, T is the length of the period; r(t) is the real interest rate at time t.

The above formula can be estimated by a discrete, i.e. an annual, quarter, monthly and other period timing. In this case, r(t) represents the forward or futures rates rather than the spot rate. If the time-dependent function of the Social discount rate is known or evaluated, the desired investment amount can be determined by continuous discounting.

Based on the definitions given to the green economy and the points of view placed on its relations with economic growth, now we consider its applications and measurements.

Green economy can be manifested in practice in the following directions:

- Production of goods and services for a qualitative and healthy lifestyle;
- Stop or at least reduce air pollution;
- Improving the quality of capital;
- Saving and efficient allocation of resources;
- Social equality;
- Biodiversity.

Undoubtedly, the factor that most negatively affects the development of the green economy is environmental pollution. The main pollutants are industrial, transport and domestic waste, including Carbon dioxide (CO2) and methane gases.

Statistics of Greenhouse gases in cross-country indicate that in the past two decades, post-industrial countries, including the United States, Germany and Japan, have decreased by about 12, 19 and 13%, respectively, and industrial developing countries, including China, Brazil, have increased by about 33 and 69%, respectively.

The question of whether the rest of the countries will also reduce pollution when a Steady-state arrives can be predicted through CO2 and economic growth dynamics, but it is difficult to find an exact answer as the solution will depend on many other factors. Each country has its own macroeconomic policy, which, in addition to socio-political factors, can stimulate or indirectly limit production, depending on unemployment, inflation, foreign trade and the stability of the national currency. It is inevitable that the green economy will fall out of the agenda when the CO2 reduction policy causes unemployment above all.

At the same time, it is desirable that the policy of reducing CO2 in each country or region be supported at a global level. In addition to the UN, international financial organizations, including the IMF, World Bank have also been active in this issue in recent times.

Many projects focused on the development of the Green Economy are mainly done by nonprofit organizations, which can operate at the expense of international organizations and foundations. They focus on two areas: environmental pollution prevention and plant breeding. As the main projects, Low Carbon Economy, Trillion Tree Campaign, Ecosia, and Trees for the Future can be shown as the reformation agenda. Trees for the Future has helped plant 35 million trees for 120,000 families in a total of 6,800 villages across Asia, Africa and America [2]. Domestic projects have also been developed in countries, with international and government funding provided in both directions.

Now let's focus on the problems in the development of the green economy. As noted above, Green Economy projects have a nonprofit look that may not be attractive to investors who are their

financial source. The expected return from industry and other traditional business settlements is an opportunity cost for eco-investment. So the dividend promised to them should be more than the average conventional interest rate and dividends. In this case, methods that are beyond market mechanisms, such as social claims should be included.

The next issue is that budget funds, which are focused on green projects, reduce the supply of funds in the financial markets. This can lead to further increases in interest rates, a reduction in investment, and a contraction of gross supply. This can ultimately increase unemployment and inflationary pressure.

According to the International Labor Organization (ILO), while a total of 78 million jobs will be reduced under the two scenarios, 103 million new types of jobs will be created in the future (Table 1).

Table 1: ILO-2019 Horizon 2030 job creation forecasts for green economy scenarios (in millions of jobs).

Horizon 2030 scenarios	Risk of job destruction	Potential job creation	Balance
Energy transition scenario	-7	+25	+18
Circular economy scenario	-71	+78	+7
Total	-78	+ 103	+25

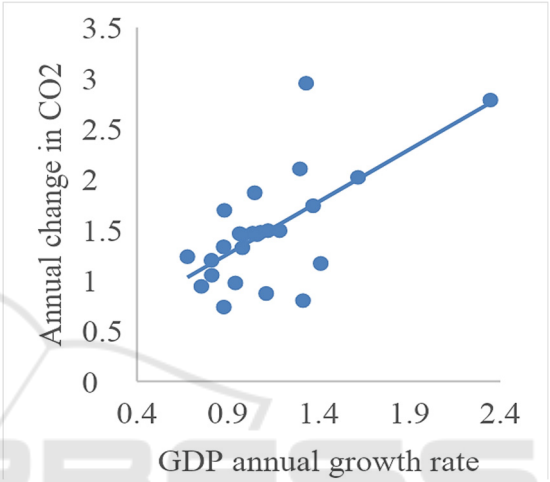
Source: ILO (ILO pdf Web, p.5)

The main issue is the provision of social assistance to the stratified population, which is likely to lose jobs, and preparing them for jobs suitable for the green economy during the transition period. According to the ILO, three sectors in the green economy are: production and destruction of water; sanitation and waste treatment; protection of nature, referring to the following professions, mainly specific to the environment and biodiversity sectors:

Transport;
Building;
Agriculture and livestock;
Forest industry;
Fishing;
Manufacture.

Also, due to the development of AI, programming and training of green projects for the green profession can be carried out in a low-cost and effective way. Even on the way to creating embodied capital, many IT and other tech professionals can keep self-employment and even create additional jobs. As it is known, a new type of capital increases the efficiency of labour, and this, in turn, increases the average salary. The increase in the gross demand of the population with increased income encourages green industries of a new type, thus the multiplicator effect will continue until the new steady state is achieved.

From the above considerations, measurement of the green economy is possible through a dual approach: examination of the dependence of reduction in greenhouse effects and biodiversity indicators on economic growth. Plotting the change in the CO2 output of countries given in 2010 and 2022 and the economic growth change in the corresponding years give the following results (Figure 1)



(Source: by authors based on data (Statista: Link) and (World Bank link)

Figure 1: Relation between economic growth and CO2 emission.

The results of Figure 1 can be formulated as follows

$$\Delta\widehat{CO2} = 0{,}326 + 1{,}0356(1-\lambda)g \qquad (4)$$

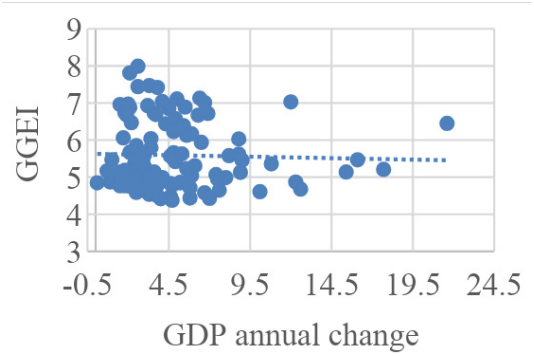
Where CoE is the change in CO2 emission, g is the economic growth rate. **λ** is the bias error of the elasticity coefficient and there is no bias when it is zero.

Now we will associate economic growth with the Global Green Economy Index. To do this, we bring this index rating of 2022 and the economic performance indicators of the same year to the regression equation and the result is as follows.

$$\widehat{GGEI} = 5{,}6301 - 0{,}008(1-\gamma)g \qquad (5)$$

Where GGEI is the predicted GGEI score value, g is the economic growth rate, γ is the bias error of the elasticity coefficient and there is no bias when γ is zero.

(5) The regression relation of the equation is reflected in Figure 2.



(Source: by authors based on data (GGEI, 2022) and (World Bank link)

Figure 2: Regression scatterplot of GDP change and GGEI score.

Thus, in each of the results we attribute, there is reverse proportionality among the indicators that represent economic growth and the green economy. That is, economic growth either increases CO2 or lowers ranking relative to the green index. This confirms our hypothesis about the Steady-state, albeit somewhat.

In fact, the fact that no country ceases to grow economically may question the application of Solow and other exogenous models. For instance, developed countries even though have lower economic growth than catching-up economies, they still have annual growth in GDP. However, many of them have reduced greenhouse pollution. To understand this, it is advisable to consider a green economy using a modified variant with endogenous models. In particular, Barro's work gives the following modification, in which the Cobb Douglass production function and the AK model are combined (Barro, 1995 p.66). This model is “asymptotically” approaching the steady state, providing economic growth at any stage of each capital accumulation. Indeed, this formulation is closer to reality and implies that the transition to the green economy can be achieved even though the level of capital accumulation is not right at the steady state but somewhere around.

As for Social discount, the green economy measure can be expressed by adjustment through it. For example, according to the Zero emission agenda by 2050, the annual CO2 reduction is 6%, and by 2030 half of this plan should be implemented effectively. Hence because discount rate is pre trimmed, according to the formulated problem we evaluate Formula (2) to obtain the following numerical result

$$\int_t^{2050} r(t)dt \approx 0.06$$

According to the Half life estimation by 2030 CO2 to be reduced by a factor of ln2/[0.06(2030-t)]. Economic growth, on the other hand, slows down to match the (4) or (5) regression coefficients, leading to a Steady state and this in turn to a green economy.

3 CONCLUSIONS

Green economics is becoming an alternative to traditional economics. This direction, formed by the Industrial Revolution and its consequences, has managed to become globally popular, despite being relatively new, and international organizations, becoming the agendas of the country's authorities.

There are various concepts about the green economy. It promotes issues such as not only preserving environmental naturalness and producing natural products but also social equality.

The question of measuring the green economy has not yet come to a clear template, as it is somewhat abstract in relation to traditionalist indicators. Nevertheless, it is now internationally listed, including the Global Green Economy Index, Green Development index.

Some green economists question the positivity of economic growth and are critical in many cases. The main thesis is that constant economic growth cannot serve to increase the elegance and social well-being of people, but rather ineffectively dispose of resources, stimulating excessive consumption. and as a rebuttal to them, the market mechanism increases not only nominal, but also real wealth, including greenery.

Through the multi-factor modification of neoclassical economic growth models through capital and non-labour human capital and Natural Resources, the processes of economic growth, transition to steady state and the green economy can be sought. The experience of developed and developing countries is in many cases consistent with this. In some idiosyncratic keys, however, the addition of endogenous models also brings the analysis closer to realism. Through Social discount, it is possible to extract the value of the traditional GDP corrected to the green economy.

We have made a brief regression analysis of Greenhouse gas capping and ggei s related to economic growth. The main problem at our disposal is the lack of online selections and the issue, which should also be analysed through the Deep Natural Sciences, is purely economic. Therefore, in perspective, we are referring to multi-factor regression analysis.

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