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## YASHIL IQTISODIYOTNI RIVOJLANTIRISH NAZARIYASI VA O‘LCHOVI MUAMMOLARI: YASHIL O‘SISH

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**Annotatsiya.** Ushbu maqolada yashil iqtisodiyot nazariyasini shakllantirish va yashil o‘shning dolzarb muammolari ko‘rib chiqiladi. Maqolada mavzuga analitik yondashilgan bo‘lib, muammolarni tahlil qilishda an’anaviy iqtisodiyot ta’limotidagi tushunchlar orqali ularga muqobil, yashil iqtisodiyotga bevosita va bilvosita ta’sir qilishi mumkin bo‘lgan koseptsiyalar qiyoslanadi. Xususan, inson kapitalining barqaror rivojlanishdagi o‘rni va eksternal ta’sirlarni boshqarish masalalariga oid pastulatlarni turli differentsial tenglamalar orqali ko‘rib chiqilib, ularni empirik baholash uchun ba’zi ekonometrikaning regression usullariga misol keltirilgan. Xulosa sifatida, ijtimoiy diskont stavkasini (SDR) optimallashtirish va Pigou soliqlari orqali eksternal ta’sirlarni tartibga solish kelajak avlod farovonligini ta’minlashning asosiy vositasi ekanligi va ushbu yo‘nalishda tadqiqot qilish ahamiyati qayd etilgan.

**Tayanch so‘zlar:** Yashil iqtisodiyot, inson kapitali, barqaror rivojlanish, eksternal ta’sirlar, ijtimoiy diskont stavkasi, DHSS modeli, yashil o‘sh.

## PROBLEMS OF DEVELOPING GREEN ECONOMY THEORY AND MEASUREMENT GREEN GROWTH

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**Abstract.** This article examines the formation of green economy theory and the current challenges of green growth. The study adopts an analytical approach, comparing alternative concepts through the lens of traditional economic theory that may directly or indirectly influence the green economy. In particular, the role of human capital in sustainable development and issues related to managing externalities are analyzed using various differential equations, and examples of econometric regression methods are provided for their empirical evaluation. As a conclusion, it is emphasized that optimizing the social discount rate (SDR) and regulating externalities through Pigouvian taxes are key tools for ensuring the welfare of future generations, and the importance of conducting further research in this direction is highlighted.

**Keywords:** Green economy, human capital, sustainable development, externalities, social discount rate, DHSS modeling, green growth.

## ПРОБЛЕМЫ РАЗРАБОТКИ ТЕОРИИ «ЗЕЛЕННОЙ» ЭКОНОМИКИ И ОЦЕНКИ «ЗЕЛЕНОГО» РОСТА

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***Аннотация.** В данной статье рассматриваются формирование теории «зелёной экономики» и актуальные проблемы зелёного роста. В статье применён аналитический подход, при котором альтернативные концепции сопоставляются через призму традиционной экономической теории, способные оказывать прямое и косвенное влияние на зелёную экономику.*

*В частности, роль человеческого капитала в устойчивом развитии и вопросы управления внешними эффектами анализируются с использованием различных дифференциальных уравнений, а также приводятся примеры эконометрических регрессионных методов для их эмпирической оценки.*

*В заключение подчёркивается, что оптимизация социальной ставки дисконтирования (SDR) и регулирование внешних эффектов с помощью налогов Пигу являются ключевыми инструментами обеспечения благосостояния будущих поколений, а также отмечается важность дальнейших исследований в данном направлении.*

***Ключевые слова:** Зелёная экономика, человеческий капитал, устойчивое развитие, внешние эффекты, социальная ставка дисконтирования, DHSS моделирование, зелёный рост.*

### INTRODUCTION

The green economy is a development model that combines increasing prosperity and social equity with reducing environmental damage and the risk of depletion of natural capital. According to the United Nations Environment Programme (UNEP), this model ensures growth in employment and income through investments aimed at reducing waste and pollution, improving energy and resource efficiency, and preserving biodiversity.

In the traditional (“brown”) economy, Gross Domestic Product (GDP) and its expenditure components are taken as the main indicators of macroeconomic welfare:

$$Y = C + I_K + G + X$$

However, this indicator does not account for environmental degradation or the welfare of future generations. According to the principles of the green economy, although current welfare may increase in unsustainable production systems, future generations become poorer due to the depletion of natural resources. Therefore, there is a need for new measures such as “ecological GDP” or the Inclusive Wealth Index (IWI):

$$IWI = K_p + K_h + K_n,$$

where:

- $K_p$  — produced (physical) capital
- $K_h$  — human capital
- $K_n$  — natural capital

**Research objective:** This study aims to evaluate the decisive role of human capital in the transition to a green economy under technological and ecological uncertainties (in the context of Malthus and Kremer debates) using econometric models, and to develop a unified measurement system for sustainable development.

## LITERATURE REVIEW

There are both direct and indirect scientific studies related to the topic, in which the concepts of economic growth and its sustainability are mainly integrated. In particular, in the works of R. Solow [15], D. Acemoglu [3], G. Mankiw [9], [10], Romer [13], Ramsey [12], R. Barro va X. Sala-i-Martin [1], and Mincer [11], these issues are examined together with human capital, while in the works of P. Dasgupta [4] and C. Groth [7], [8], they are studied in conjunction with renewable resources. Additionally, the works of C. Gelsomina va P. Chiara [2], M. Florio and E. Sirtori [6] are devoted to the social discount rate.

## METHODS

In the article, human capital (H) is considered the main determinant of the green economy, as it requires fewer natural resources compared to other factors in creating added value. The analysis methodology is based on the following mathematical and econometric models.

Almost all variables, according to their economic meaning, belong to the following set of numbers and, if they are not constant, are functions of the time-dependent variable  $t$ :

$$\mathbf{x} \equiv \mathbf{x}(t) = \mathbf{x}_t, t \in \mathbb{Z} \subset \tau \in \mathbb{R} \cap \mathbb{R}^+$$

$$\beta_i = \text{const}$$

Vector-valued variables are written in bold letters:

$$\mathbf{x} = (x_1, x_2, \dots, x_n)$$

As used by the authors in the literature, in this article  $\log$  denotes the natural logarithm, i.e.,  $\log a = \ln a$ .

The functions are assumed to be continuous and differentiable multiple times over their domains of definition.

Also we accept other assumptions as they are given in references:

- All variables are assumed to be finite and economically meaningful, i.e., they take non-negative values where required ( $x(t) \geq 0$  for relevant economic quantities such as capital, consumption, and output).
- The model operates under perfect foresight (or rational expectations), meaning that economic agents correctly anticipate future variables and policy changes.

- Production functions are assumed to be strictly concave, continuously differentiable, and satisfy the Inada conditions, ensuring diminishing marginal returns to inputs.
- Markets are assumed to be perfectly competitive, and prices adjust freely to ensure equilibrium.
- There are no external shocks unless explicitly introduced; the system evolves deterministically over time.
- Parameters are stable over time unless otherwise specified.
- The economy is closed (or open, if relevant—specify accordingly) and operates under given resource constraints.
- The time horizon is either infinite or sufficiently long to analyze long-run equilibrium behavior.
- Transversality conditions are satisfied to guarantee optimal solutions in intertemporal optimization problems.
- If uncertainty is considered, stochastic processes are well-defined with finite moments and known distributions.

### 2.1. Relationship between human capital and income

Taking into account four main factors determining the size and quality of human capital (educational, medical-biological, socio-cultural, and economic), a Mincer-type econometric model is applied:

$$\log Y = \log Y_0 + rS + \beta_1 E + \beta_2 SE^2$$

where:

- S — years of schooling
- E — work experience
- r — marginal return to education

### 2.2. Modeling the production function

The production function adapted to the green economy expands its variables:

$$Y = A \cdot F(K, L, H, N, T)$$

The marginal rate of technical transformation in the factor space is calculated as:

$$MRTT_{h \rightarrow x} \frac{dh}{d \rightarrow_x} = - \frac{\partial f / \partial h}{\partial f / \partial \rightarrow_x}$$

### 2.3. Human capital dynamics and discounting

Now we consider the main computational approaches of human capital in economic growth theory. The accumulation and motion of human capital are expressed by the following differential equation:

$$h_x = h_0 + \int_0^x G(s_u, l_u, h_u, v + u) du, \quad h_0 \geq 0$$

Similar to physical capital, the law of motion of human capital is:

$$\dot{h}_x \equiv \frac{dh_x}{dx} = G(s_x, l_x, h_x, t), \quad 0 \leq s_x + l_x \leq 1$$

If  $w(t, S)$  represents the real wage per hour at time  $t$  for an individual who has studied for  $S$  years and works  $l$  hours per day, then the expected present value of lifetime earnings at time  $v$  is:

$$HV(v, S) = \int_{v+S}^{\infty} E_v[w_t(S)l_{t-v}(S)]e^{-r(t-v)} dt$$

To account for uncertainty in life expectancy, a stochastic variable  $X$  is introduced:

$$HV(v, S) = \int_{v+S}^{\infty} w_t(S)e^{-r(t-v)}[l * P(X > t - v) + 0 * P(X \leq t - v)] dt$$

#### 2.4. The problem of renewable and non-renewable resources

One way to describe sustainable or green growth is to incorporate renewable and non-renewable resources into aggregate models. In particular, a dynamic model that takes renewable resources into account can be represented as follows.

$$\begin{aligned} Y_t &= F(K_t, L_t, R_t, t), & \frac{\partial F}{\partial t} &\geq 0, \\ \dot{K}_t &= Y_t - C_t - \delta K_t, & \delta &\geq 0, K_0 \geq 0 \\ L_t &= L_0 e^{nt}, & n &\geq 0 \end{aligned}$$

In this case,  $(R_t)$  represents inputs consisting of renewable resources. The model with non-renewable resources differs from the above only by the inclusion of the equation describing this type of resource,  $(S_t)$ , and the coefficient reflecting its depletion rate,  $(u_t)$ :

$$\dot{S}_t = R_t \equiv -u_t S_t, \quad S_0 > 0$$

This model is known as the Dasgupta–Heal–Solow–Stiglitz model, or the DHSS model.

#### 2.5. Empirical analysis specification

To test all indicators and estimate panel data, a comprehensive regression model is developed:

$$\log GEI_i = \beta_0 + \beta_1 \log(HC_{it}) + \beta_2 \log Uncert_{it} + \beta_3 Ext_{it} + \beta_4 SDR_{it} + \sum \gamma_k X_{kit} + \alpha_i + \delta_t + \varepsilon_{it}$$

This model is used to test the Kremer and Malthus hypotheses and to evaluate the effects of carbon taxes, uncertainty, and the social discount rate (SDR).

### RESULTS

The analysis of the models produced the following economic and analytical results:

#### 3.1. Substitution efficiency of production factors

In the production function  $Y = A \cdot F(K, L, H, N, T)$ , increasing the share of human capital (H) optimizes the burden on other resources. In particular, high “green” human capital leads to:

- K (physical capital): less depreciation and longer service life
- L (labor): reduced working hours and increased leisure time
- N (natural resources): significant conservation
- T (land resources): more free land converted into recreational areas

The macroeconomic expenditure equation under sustainable growth becomes:

$$Y = C + I_k + I_h + G + X$$

### 3.2. Effective discount rate of education

By solving the wealth maximization problem, the “first-order condition of education” is obtained:

$$\frac{\partial HW}{\partial S}(v, S) = \dots = HW(S) \left[ \frac{d \log h(S)}{dS} - (r + m - n) \right] = 0$$

Its solution: keltiriladi

$$\frac{h'(S)}{h(S)} = r + m - g \equiv \tilde{r}$$

Here,  $\tilde{r}$  is called the effective discount rate for decision-making regarding education investment.

### 3.3. Role of the social discount rate (SDR)

The results show that how current society values future generations directly affects project efficiency. A high SDR makes long-term environmental projects economically unattractive, while a low SDR strongly stimulates green investments.

Assuming utility is derived from consumption, the problem of maximizing intertemporal utility is formulated as:

$$\max[U = \int_0^{\infty} u[c(t)] e^{-(\rho-n)t} dt]$$

subject to,

$$\dot{a} = w + ra_t - c_t - na_t$$

where:

- U — present value of utility
- u — utility function
- c(t) — consumption over time
- $\rho$  — time preference parameter
- n — population growth rate
- $\dot{a}$  — change in assets
- w — wage
- $a_t$  — assets at time  $t$

Depending on whether  $\rho$  is greater or smaller than n, present consumption becomes more or less valuable than future consumption, ultimately affecting resource allocation.

## DISCUSSION AND CONCLUSION

### Managing market failures and externalities

The transition to a green economy does not occur automatically due to the presence of externalities. Negative externalities (pollution, carbon emissions) are not included in production costs in traditional economies. Conversely, positive externalities (scientific research, environmental education) benefit society but are underfunded by free markets.

Government regulators must address these market failures through:

- Pigouvian taxes (e.g., carbon taxes)
- Subsidies supporting positive innovations
- Pollution quota markets based on the Coase theorem

### **Synthesis of Malthus and Kremer approaches**

The study supports the Kremer hypothesis in managing climate and technological changes under uncertainty. That is, population and consumption growth do not necessarily lead to stagnation as predicted by Malthus, provided that society effectively develops “green” human capital. Rapid technological progress relative to ecological constraints ensures the sustainability of the system.

### **CONCLUSION**

The green economy, human capital development, and the regulation of externalities form an inseparable unified mechanism. The success of this mechanism depends directly on the scale of investments in human capital—including “green jobs” and ecological thinking – and on how fairly future generations’ interests are discounted in macroeconomic policy.

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