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USE OF GMDH FOR INVESTIGATION OF IMPACT OF NON-INCOME COMPONENTS ON HDI

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У статті аналізується вплив макроекономічних показників на рівень людського розвитку держав світу. Взято дані ООН про розвиток країн за 2011 рік. Країни поділені на групи відповідно до класифікації ООН. Виділено та проаналізовано показники, які впливають на рівень розвитку кожної з груп. Для побудови моделей, що описують залежність індексу розвитку людського потенціалу від макроекономічних показників, використаний комбінаторний алгоритм МГУА.
Ключові слова: комбінаторний алгоритм МГУА, індекс людського розвитку, макроекономічні показники

Impact of macroeconomic indices on the development level of countries is analysed in the article. UN data about human development for 2011 are used. Countries are divided into groups according to UN methodology. The factors influencing on the development level for every group were chosen and analysed. Combinatorial GMDH algorithm was used to build models describing dependence of human development index on macroeconomic factors.
Keywords: combinatorial GMDH algorithm, human development index, macroeconomic data

В статье анализируется влияние макроэкономических показателей на уровень человеческого развития государств мира. Взяты данные ООН о развитии стран за 2011 год. Страны поделены на группы в соответствии с исследованиями ООН. Выделены и проанализированы показатели, которые влияют на уровень развития каждой из групп. Для построения моделей, описывающих зависимости индекса развития человеческого потенциала от макроэкономических показателей, использован комбинаторный алгоритм МГУА.
Ключевые слова: анализ, комбинаторный алгоритм МГУА, индекс развития человеческого, макроэкономические показатели

1. Introduction

United Nations Development Program (UNDP) is the United Nation's (UN) global development network, advocating for change and connecting countries to knowledge, experience and resources to help people build a better life [1]. UNDP works in four main areas: poverty reduction; democratic governance; crisis prevention and recovery; environment and sustainable development.

UN specialists annually prepare reports about current development of the countries, where all countries are ranked by human development index [2].

The goal of this work is to analyze what factors affect human development level by building dependencies by the group method of data handling (GMDH) and to analyze received result from the point of view of economic situation. Such models may be used by specialists for current economic situation analysis of the country in order to find possibilities for improvement of level of country development, particularly Ukraine. Data for 2011 were used for analysis.

Besides, it was shown how GMDH can be used for revealing of dependencies in social and economic data and their analysis. Models are developed by Combinatorial GMDH algorithm [3, 4]. Combinatorial GMDH algorithm is a method of structural-parametric identification when structure and model parameters are selected in the process of model building unlike regression analysis that uses a fixed model

structure. Inductive GMDH algorithms give possibility to find interrelations in data automatically, and to select optimal structure of model.

Models for forecasting of human development index of Ukraine were developed in the works [5-8]. This forecast enables to see the change of index in the future and can be used for analysis by specialists. GMDH is the method which enables building of long-term forecast. The models built by this method using external bias criterion are more noise immunity than ones built by other methods.

The task of the present work is to find out what factors are the most influential for human development in countries with different development levels. Is income the main factor for human well being? There are assumptions that people in highly developed countries benefit from reliable social system and comprehensive public health system. Their human development potential lies in the field of non-income stimulus. While population of developing countries suffers from poverty and often have no resources to satisfy their basic needs. So the income factor is the most important for them for achieving minimum standards of living. Therefore, the purpose of this work is to verify such assumptions as well.

2. Human development index as factor of development level of countries

Human development can be defined as enabling people to develop their full potential and lead productive, creative lives in accordance with their needs and interests. However, it took a long time before mankind accepted the rather simple truth that the goal of development is to enhance everyone's abilities and freedoms. Over time there has been a better understanding of the social consequences of economic development, of the increasing inequality between rich and poor countries that accompanied globalization and above all an acknowledgement by governments and the public at large that not only is human development achievable, but that it has practical meaning for social and economic progress and the overall prosperity of nations and states. Therefore, the dynamics of human development analysis have become an issue of research for such leading world organizations as the UN, World Bank and other international organizations.

The Human Development Report is an independent publication commissioned by the United Nations Development Programme. Its editorial autonomy is guaranteed by a special resolution of the General Assembly which recognizes the Human Development Report as "an independent intellectual exercise" and "an important tool for raising awareness about human development around the world" [1].

Twenty years ago, the Human Development Index (HDI) was proposed as an alternative to conventional assessments of development based on measures of per capita income. It complements income with health and education indicators. Human Development Index classifications are relative – based on quartiles of HDI distribution across countries and denoted very high, high, medium and low HDI. Because there are 187 countries, the four groups do not have the same number of

countries: the very high, high and medium HDI groups have 47 countries each, and the low HDI group has 46 countries.

The components of HDI are life expectancy at birth, mean years of schooling, expected years of schooling, gross national income (GNI) per capita, GNI per capita rank minus HDI rank, and non-income HDI value.

Table 1 presents a fragment of data sample describing Human Development Index and its components for the group of countries with very high human development in 2011.

Table 1. Fragment of input data sample for the countries with very high human development in 2011

№	Country	X_1	X_2	X_3	X_4	X_5	X_6	Y_1
1	Norway	81,1	12,6	17,3	47 557	6	0,975	0,943
2	Australia	81,9	12,0	18,0	34 431	16	0,979	0,929
3	Netherlands	80,7	11,6	16,8	36 402	9	0,944	0,910
4	United States	78,5	12,4	16,0	43 017	6	0,931	0,910
5	New Zealand	80,7	12,5	18,0	23 737	30	0,978	0,908
6	Canada	81,0	12,1	16,0	35 166	10	0,944	0,908
7	Ireland	80,6	11,6	18,0	29 322	19	0,959	0,908
8	Liechtenstein	79,6	10,3	14,7	83 717	-6	0,877	0,905
9	Germany	80,4	12,2	15,9	34 854	8	0,940	0,905
10	Sweden	81,4	11,7	15,7	35 837	4	0,936	0,904
11	Switzerland	82,3	11,0	15,6	39 924	0	0,926	0,903
12	Japan	83,4	11,6	15,1	32 295	11	0,940	0,901
13	Hong Kong, China (SAR)	82,8	10,0	15,7	44 805	-4	0,910	0,898
14	Iceland	81,8	10,4	18,0	29 354	11	0,943	0,898
15	Korea (Republic of)	80,6	11,6	16,9	28 230	12	0,945	0,897
16	Denmark	78,8	11,4	16,9	34 347	3	0,926	0,895
17	Israel	81,6	11,9	15,5	25 849	14	0,939	0,888
18	Belgium	80,0	10,9	16,1	33 357	2	0,914	0,886
19	Austria	80,9	10,8	15,3	35 719	-4	0,908	0,885
20	France	81,5	10,6	16,1	30 462	4	0,919	0,884

X_1 – life expectancy at birth (years);

X_2 - mean years of schooling (years);

X_3 - expected years of schooling (years);

X_4 - gross National Income (GNI) per capita (Constant 2005 PPP\$);

X_5 - GNI per capita rank minus HDI rank;

X_6 - nonincome HDI;

Y_1 - Human Development Index (HDI).

Thus, samples for the all four groups of countries are obtained.

The values of all these components should be scaled to build an adequate model of dependences of HDI on macroeconomic data. For this purpose each factor's data are divided by its maximum value.

2. Dependences of HDI construction by Macroeconomic Data

Combinatorial GMDH algorithm was chosen for description of dependences of HDI on its components. It is a method of automatic model building based on data observation [3, 4]. This method is grounded on the principles of induction, which is the transition from specific to general. Unlike regression analysis which uses a fixed model structure, combinatorial GMDH algorithm is a method of structural-parametric identification.

For every group of countries models describing dependency of HDI on other factors were built by GMDH algorithm.

Therefore, for the HDI 1, which characterizes a group of countries with very high level of development, the following model was developed.

$$Y_1 = 0,0345 - 0,0035X_3 + 0,0815X_4 - 0,0312X_5 + 0,9087X_6.$$

Value of criteria: $AR = 0,68649\text{E-}04; \quad BS = 0,6439\text{E-}05,$

when AR is regularity external criterion, BS is bias external criterion [4].

Dependence of real and modelled HDI values on macroeconomic data for a group of countries with very high level of development is shown in the Fig. 1.
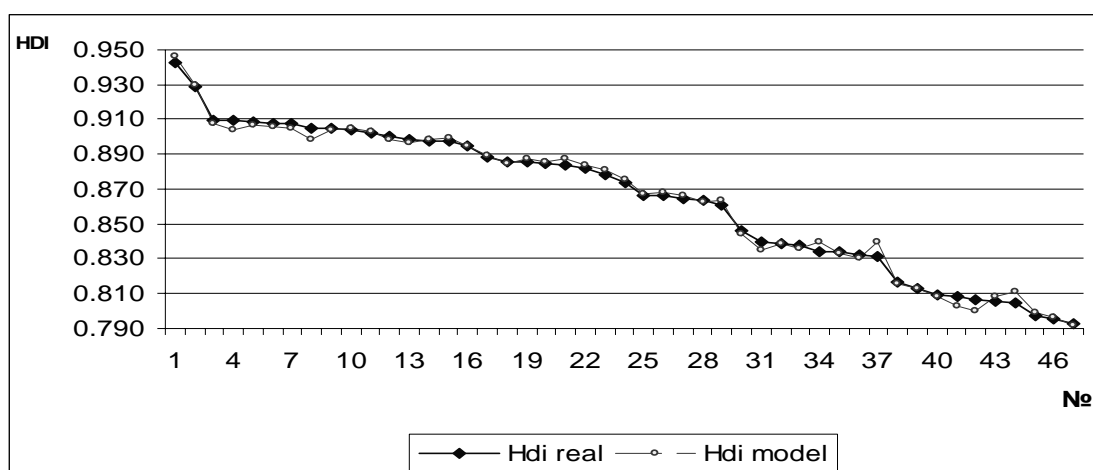

Fig. 1. Comparison of Real HDI 1 and Modeled HDI 1

Similar model was built for the second group of countries with high development level:

$$Y_2 = -0,0469 + 0,6998X_1 + 0,2242X_2 + 0,1331X_3 + 0,0242X_6$$

Value of criteria: $AR = 0,000059416;$ $BS = 0,14473E\text{-}04.$

Fig. 2 shows obtained dependence of real and modeled values for 47 countries from the group with high development level.
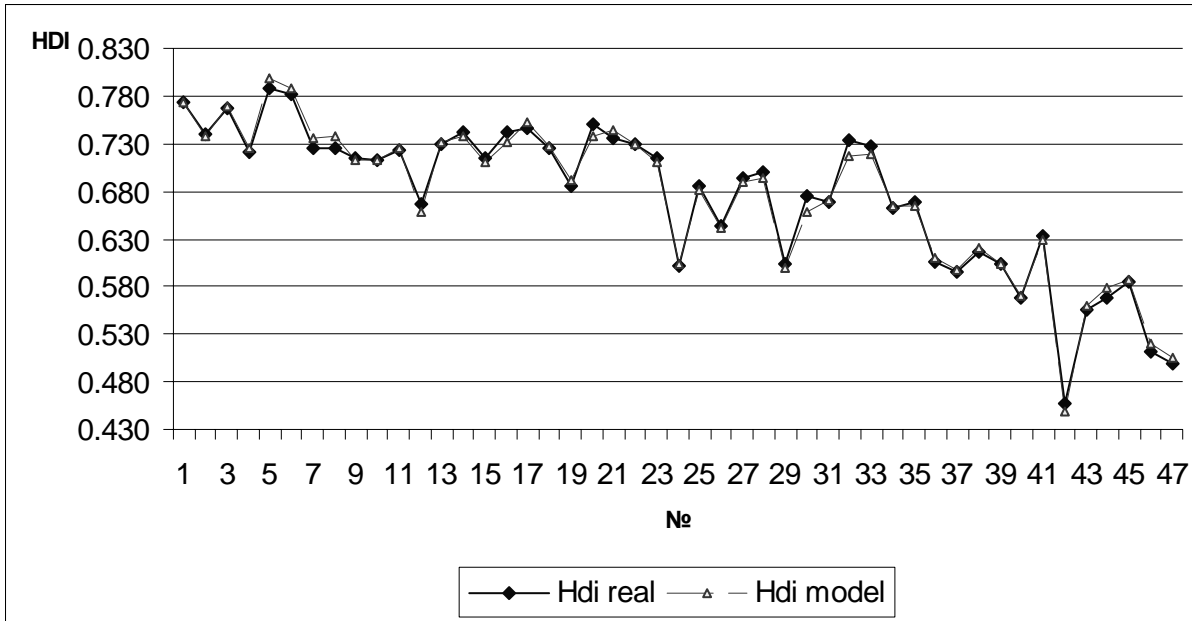

Fig. 2. Comparison of Real HDI 2 and Modeled HDI 2

Expected years of schooling are a number of years of schooling that a child of school entrance age can expect to receive if prevailing patterns of age-specific enrolment rates persist throughout the child's life. Mean years of schooling is an average number of years of education received by people ages 25 and older, converted from education attainment levels using official durations of each level.

The following model was developed for the third group of countries with middle development level

$$Y_3 = -0,0869 + 0,3343X_1 + 0,4312X_2 + 0,2175X_3 + 0,1237X_4 + 0,0632X_5 + 0,0319X_6$$

Value of criteria: $AR = 0,000090547;$ $BS = 0,548818E\text{-}04.$

Fig. 3 shows dependence of real and modeled values for 47 countries from the group with middle development level.
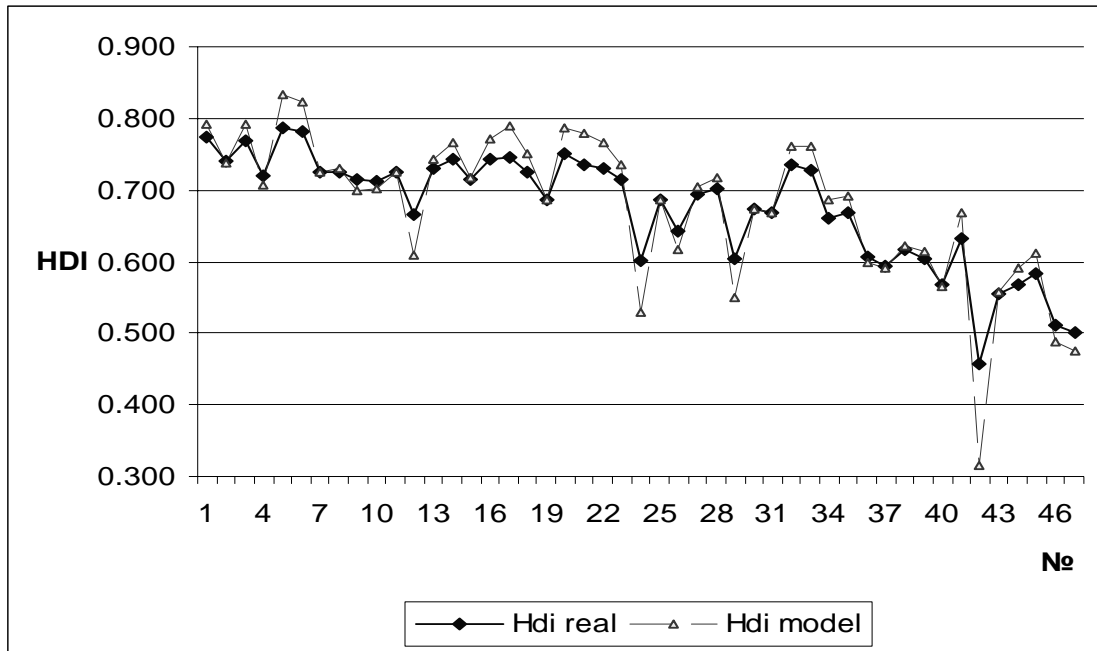
Fig. 3. Comparison of Real HDI 3 and Modeled HDI 3

Countries with low development level are included in the fourth group. The following model is developed for them:

$$Y_4 = -0{,}2688 + 0{,}7612X_2 + 0{,}3747X_3 + 0{,}2689X_4$$

Value of criteria: $AR = 0.000189805;$ $BS = 0.15863653\text{E-}03,$

Dependence of real and modeled HDI values for the 47 countries from the fourth group is shown on the Fig. 4.
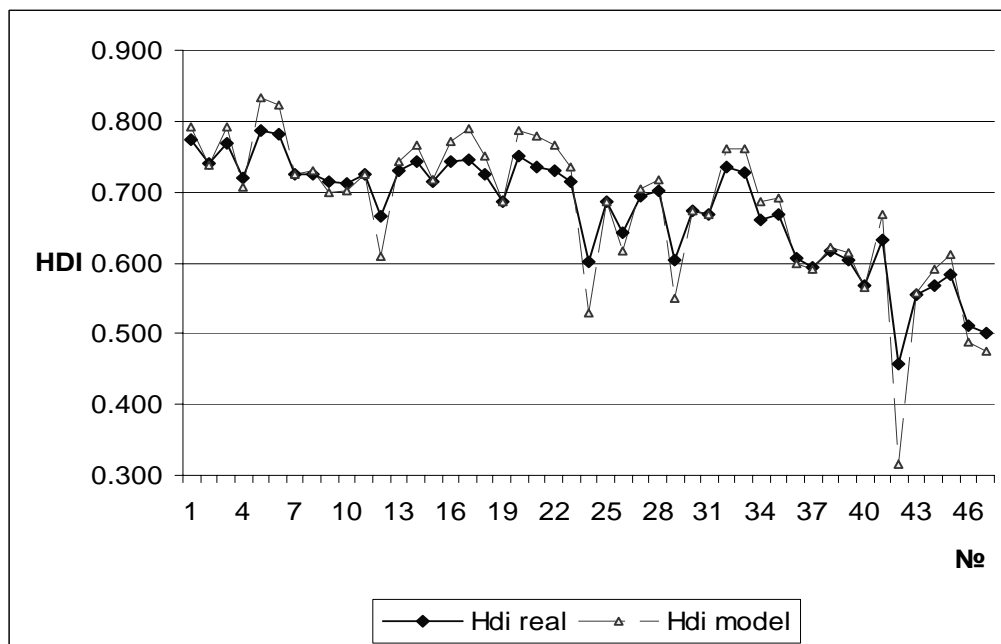

Fig. 4. Comparison of Real HDI 4 and Modeled HDI 4

Life expectancy at birth is a number of years a newborn infant could expect to live if prevailing patterns of age-specific mortality rates at the time of birth stay the same throughout the infant's life.

GNI per capita rank minus HDI rank is the difference in rankings by GNI per capita and by the HDI.

Non-income HDI is the value of the HDI computed from the life expectancy and education indicators only.

As we can see from Fig. 1 – 4, models built with GMDH algorithm describe HDIs' dependences on their components very preciously in groups of countries with very high and high levels of development. To build an efficient model for the countries with medium and low level of development we should extend our sample. It is calculated just with health and education – and thus without the income component. In other words, the value-added part of HDI is precisely in its non-income components.

Since factors influencing HDI were analyzed, data sample was extended with new factors which may affect development level of countries from these groups.

X_7 – share of multidimensional poor with deprivations in environmental services: clean water;

X_8 – share of multidimensional poor with deprivations in environmental services: improved sanitation;

X_9 – share of multidimensional poor with deprivations in environmental services: modern fuels;

X_{10} – ecological footprint (hectares per capita);

X_{11} – greenhouse gas emissions per capita;

X_{12} – urban pollution.

X_{13} – satisfaction with air quality (% satisfied);

X_{14} – satisfaction with water quality (% satisfied);

X_{15} – urban (% of total).

It should be noticed that data presented in UN report contain quite a lot of gaps, so only those countries with full data were chosen.

Thus, the following model of HDI was obtained for 24 countries with medium level of development:

$$Y_3^* = -0,054906 + 1,06186X_1 + 0,059X_3 - 0,099X_5 + 0,02446X_6 + 0,029X_8$$
$$- 0,0275X_9 - 0,0105X_{11} - 0,018X_{12}$$

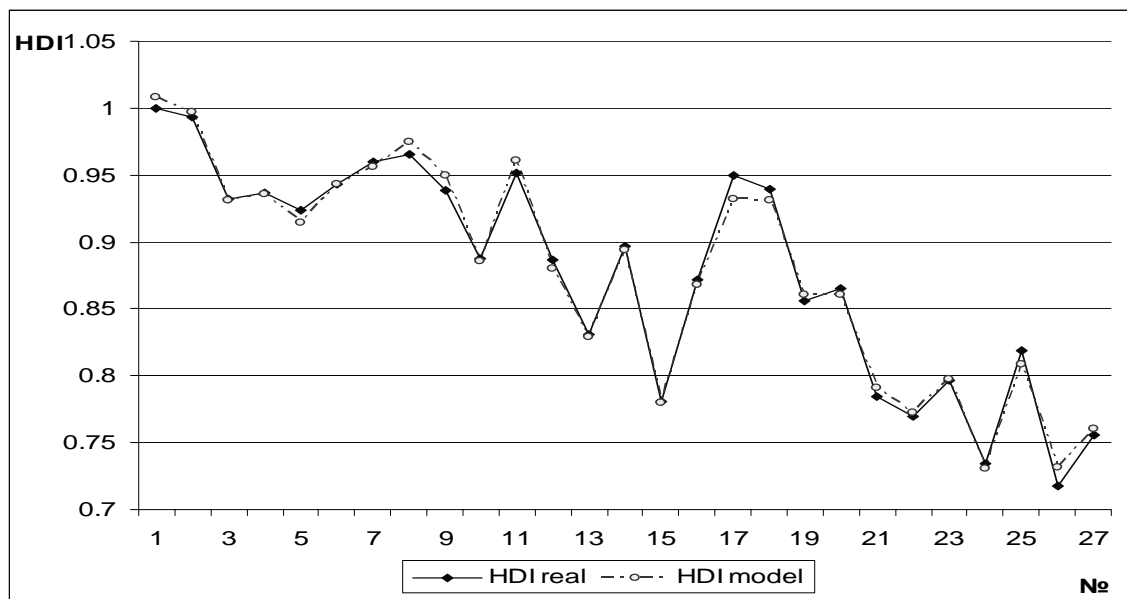Value of criteria: $AR = 0,00009$; $BS = 0,5488\text{E-}04$.

Fig. 5. Compari   son of Real HDI 3 and Modeled HDI 3 Based on Extended
Data Sample

The following model of HDI was obtained for 27 countries with low level of development

$$Y_4^* = -0,2127 + 0,7266X_2 + 0,4023X_3 + 0,2245X_4 - 0,0187X_5 - 0,013X_{11} -$$
$$- 0,0259X_{12} + 0,0167X_{14} + 0,0081X_{15}$$

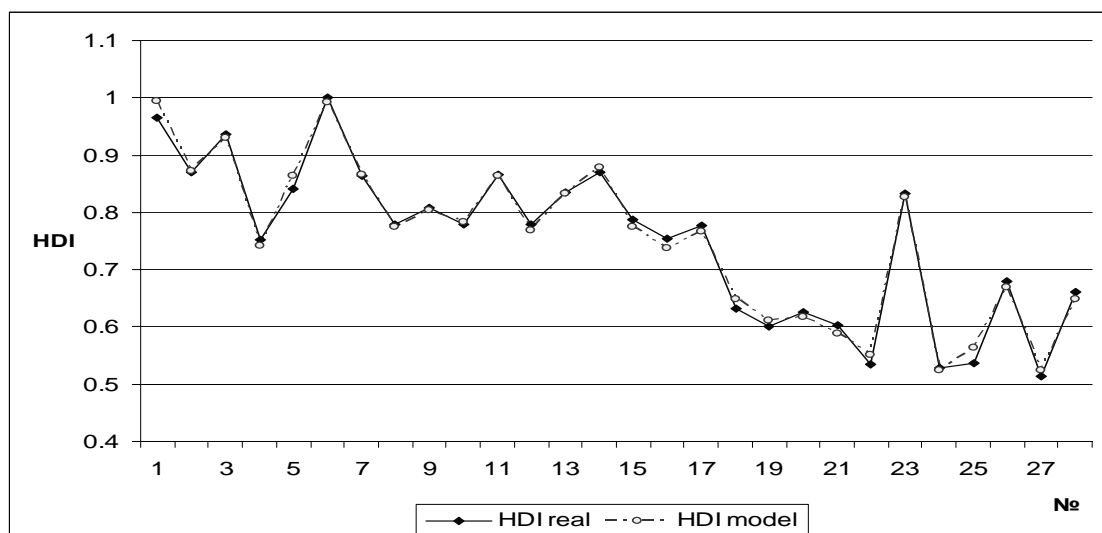Value of criteria: $AR = 0,0002;$ $BS = 0,9425.$

Fig. 6. Comparison of Real HDI 4 and Modeled HDI 4 Based on Extended Data
Sample

3. Obtained Dependences Analysis for Groups of Countries with Different Levels of Development

As we can see non-income HDI is the most influential factor for the first group of states. So population of countries with very high development level seeks for potential in further achievements predominantly not in the material well-being. They are more interested in such non-income components of HDI as health and education. Problems of healthy style of life, relationships, civil liability are the most important for them. They consider economic challenges rather from the point of view of possible threats of illegal migration, negative influence of global economic and political processes, interferences of international organizations into the internal affairs of their countries.

Rather high level of income allows people from the second group to enjoy their well-being. From the other side, inequality in access to medical and educational services, gap between rural and urban population often prevent them from living long. As high value of factor of life expectancy at birth for HDI 2 shows, that the same factors negatively influence on the human development level and life span as well.

Refined model of HDI 3 reveals even stronger dependence of their human development level on life expectancy at birth than for the countries from the second group. Taking into consideration low level of income, challenges faced by people from the third group become more menacing. Also the combination of high infant mortality and deaths in young adulthood from accidents, wars, and childbirth, may lower the overall life expectancy in this group.

Mean years of schooling is the most important factor for human development in the fourth group. Refined model emphases on importance of factors connected with schooling. Education is a powerful asset in overcoming poverty. Adult literacy is still unachieved goal for a lot of people in the poorest countries. Going to school means to provide a child with minimum standards of living.

People are the real wealth of nations. Impressed by the rise and fall of national incomes (as measured by GDP), we tend to equate human welfare with material wealth. The importance of GDP growth and economic stability should not be understated: both are fundamental to sustained human progress, as is clear in the many countries that suffer from their absence. But the ultimate yardstick for measuring progress is people's quality of life.

Therefore, from the stated above it can be concluded that for countries from all four groups income is not the most influential factor for human development. The GNI per capita turned out not to be the decisive factor for any group of countries even with low and middle level of development. Obtained dependences show, that healthy and education are the most necessary assets for human development potential for people from all over the world.

Therefore the human development includes not only economic development, but also the basic capabilities for living a long and healthy life, being educated, having a decent standard of living, enjoying political and civil freedoms to participate in the life of one's community, especially the enforcement of human rights, while also seeking to preserve a healthy environment.

Summary

Macroeconomic data were analysed in the article. Use of GMDH algorithm gave possibility to build an adequate model of dependences of HDIs on their components according to the levels of human development in the four groups of countries. The most influential factors were revealed for each group. Non-income part of HDI turned out to be the most important for human development in the whole world.

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