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Assessment of Measures to Combat Poverty Based on a Global Multi-Country Hybrid Econometric Model

Abdykappar Ashimov[1*], Yuriy Borovskiy[2], Dauren Aidarkhanov[3]

[1)]Kazakh National Research Technical University named after K. Satpayev, Almaty, Kazakhstan

E-mail: ashimov37@mail.ru

[2)]Kazakh National Research Technical University named after K. Satpayev, Almaty, Kazakhstan

E-mail: yuborovskiy@gmail.com

[3)]Kazakh National Research Technical University named after K. Satpayev, Almaty, Kazakhstan

E-mail: aidarkhanov@inbox.ru

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Abstract: A hybrid global multi-country econometric model describing the interacting economies of 62 countries and the rest of the world is presented. The hybrid Model was built by developing and combining two macroeconomic models: the Fair's quarterly model and the IMF's annual macroeconomic balance model (using two developed interaction interfaces between these models). The possibility of transferring the results of computational experiments based on the Model to practice (the Model verification) using two approaches is discussed: parametric control theory methods and known methods of testing the results of econometric models. A number of parametric control problems was set and solved, aimed at maximizing gross domestic product per capita at purchasing power parity at the levels of individual countries and their associations. One such problem additionally takes into account the conditions of convergence of economic growth of five countries of the Eurasian Economic Union. The optimizable tools of these problems are sets of instruments of monetary, exchange rate and fiscal policy with appropriate restrictions. The solution results of the mentioned problems were used to estimate the rate of change in poverty levels in the respective countries. These results demonstrate the advantages of coordinated macroeconomic policies at the levels of country groupings in comparison with the levels of individual countries that are members of such groupings.

Keywords: Poverty rate, convergence, global multi-country hybrid econometric model, coordinated macroeconomic policy, theory of parametric control.

1. INTRODUCTION

The problem of overcoming hunger and poverty is being addressed by the international community in major development objectives in the Declaration for the New Millennium [17] and in the subsequent international agreement of 2015 with the new sustainable development goals. Poverty reduction has become one of the performance criteria of social and economic systems. The significance of the problems associated with poverty and income distribution in terms of economic policy-making necessitates that the social consequences of economic shocks and economic policies are considered [4, 15].

[*] Corresponding author: ashimov37@mail.ru

In [14] poverty is measured by the incomes of the poorest 20% and 40% of the population, showing that an increase in GDP growth rates leads to a direct increase in the growth rates of average incomes of the poorest 40% of the population in a one-to-one ratio.

In [13] the following empirical model is obtained by evaluating the relationship between the change of poverty rate and the economic growth rate for 62 countries using the nonlinear least squares method:

$$\textit{Rate of poverty reduction} = [-9.33 \times (1 - G)^3] \times \textit{Economic growth rate}. \quad (1.1)$$

Here G is the Gini index, *Economic growth rate* = growth rate of GDP per capita. In (1.1), the rate of change in the proportion of people with a standard of living below the poverty line was used as the *Rate of poverty reduction*.

For example, in a country with a low level of inequality, where the Gini index is 0.30, the proportion of people living below the poverty line will decrease by half in 10.5 years if the annual growth rate of GDP per capita is 2%. In contrast, in a country with high inequality, where the Gini index is 0.60 with the same economic growth, this result will take 57 years.

In [3, 6-7] it is proposed to implement an impact assessment of economic policy measures on poverty based on the mathematical models of macroeconomic systems. However, the mentioned papers do not consider the simultaneous impact assessment of monetary, exchange rate and fiscal policy tools on poverty rates.

In [10], on the basis of a multi-country econometric model, the exchange rate of a country's national currency per unit of US dollar is estimated as a regression function of the interest rate ratio and price level ratio of the national economy and anchor economy. In the paper, Fair considers the impact of monetary policy measures, government consumption (for the US) and fiscal policy measures on some macro indicators (GDP, investments, etc.), but does not consider a simultaneous impact assessment of measures in the fields of monetary, exchange rate and fiscal policy instruments on poverty rates.

In [12] only the assessment of effective equilibrium exchange rates of the national currencies of the countries under review is carried out on the basis of relevant statistical data.

In this paper, a global multi-country hybrid econometric model based on the developed quarterly Fair multi-country macroeconomic model [10] (hereinafter - Fair model), the annual International Monetary Fund multi-country econometric model [12] (hereinafter - IMF model) and the development of two interaction interfaces for the advanced Fair model and the IMF model is proposed. The conditions for transferring the computational experimental results based on the built model to practice are evaluated. In this paper, GDP per capita at purchasing power parity is taken as the main optimality criterion of optimization problems. The simultaneous impact assessment of measures of tools in the areas of monetary, exchange rate and fiscal policies on poverty and the convergence of the adopted poverty rate at the regional union level and global level by setting and solving a number of extreme problems using methods of parametric control theory is carried out.

2. BUILDING A GLOBAL MULTI-COUNTRY HYBRID ECONOMETRIC MODEL

A global multi-country hybrid econometric model (hereinafter referred to as Model) was built to assess the measures of influencing the tools of monetary, exchange rate (as part of effective exchange rate evaluation), and fiscal policy on the adopted poverty rate and convergence of the indicator.

The model was built in accordance with the following steps.

Step 1 Selection of the basic structures of the econometric models for building the Model.

Step 2 Development of the basic structures of econometric models.

Step 3 Development of the interaction interfaces of the developed basic structures of the econometric models for building the Model.

Step 4 Preparing and testing time series and panel data for use in the reconstruction of the relevant regression functions and the interaction interfaces in the developed basic structures of the econometric models.

Step 5 Parameter estimation of the regression functions of the developed Fair model by the two-step least squares method.

Step 6 Parameter estimation of the panel regression functions of the IMF model by the generalized method of moments [5].

Step 7 Parameter estimation of the regression function of the first output interface in the IMF model to the input of the Fair model to transfer annual effective exchange rate to input of the Fair quarterly model.

Step 8 Estimation of smoothing parameters in the second interface of the outputs of the Fair quarterly model to the inputs in the annual IMF model.

Step 9 Building the Model.

Building the Model within the framework of the proposed algorithm is as follows.

In accordance with Step 1 and the designation of the Model, based on the analysis of the available literature for multi-country econometric models, the Fair multi-country econometric model [10] and the IMF multi-country econometric model [12] were selected as the source of basic structures.

The Fair model was selected as the initial basic structure to build the Model, because it provides its designation if we use effective equilibrium exchange rates as an estimate of exchange rates.

The IMF model was also selected as the initial basic structure for building the Model under the following conditions:

- the values of the fundamental factors to calculate the effective equilibrium rates, providing for the internal and external equilibrium [12] based on the Fair model were used as basic data;
- the IMF model should be used together with the Fair model.

Thus, while creating relevant interfaces of their interaction, the hybrid of the Fair model and the IMF model will provide the designation of the Model.

In accordance with Step 2 of Model building, the Fair model was developed as follows.

The basic identities for each *i*-th country were supplemented by the descriptions of the process of formation of the state budget and public debt. The influence of the level of the world crude oil price on the economies of the countries under consideration was taken into account.

The descriptions of conditions of economic integration in the areas of inflation state budget deficit and public debt, with due account of their effects on the behavior of the economic sectors (i.e., households, firms, financial and foreign sector) were further included into the descriptions of the countries of the Eurasian Economic Union (hereinafter, EAEU) consisting of Kazakhstan, Russia, Belarus, Kyrgyzstan and Armenia.

In order to improve the accuracy of prediction, the GDP deflator in the Fair model was presented by disaggregating through the following deflators: household consumption; fixed capital accumulation; government consumption; and exports and imports.

The Fair model's basic identities were also supplemented by the corresponding expressions for the fundamental factors [12] of the IMF model based on endogenous variables.

In accordance with Step 3, as the basic structure of Interface 1, which converts the annual effective equilibrium exchange rate of the national currency of *i*-country into the corresponding observable quarterly exchange rate, the RU-MIDAS model was adopted [11]. Indicators of monetary and exchange rate policy as well as an indicator of a cyclical factor were added as explanatory variables to the basic structure in the model of the first interface adopted in the paper.

In our work, the following model of the moving average filter was adopted as the model of the 2nd interface that converts the output ($X_{i,t}$) - the *i*-th quarterly indicator of the developed Fair model to the corresponding annual indicator ($\tilde{X}_{i,T}$) of the IMF model [2]:

$$\tilde{X}_{i,T} = \sum_{j=-2}^{2} \varphi_{i,j} X_{i,t+j} \,, \tag{2.1}$$

Here, each calculated year T corresponds to the second quarter of this year - t, $\varphi_{i,j}$ is the filter smoothing parameter.

At Step 4, the preparation and testing of time series and panel data to build the corresponding regression functions is carried out in the Eviews econometric environment. In doing so, testing and preparation of each time series is limited to estimation of the presence of seasonality, emissions and the subsequent correction of the considered series.

Preparing and testing panel data are reduced to the formation of the corresponding panel data by gluing together time series, and their testing is connected with the test results of the subsequent regression functions. If the test results for the corresponding regression functions meet the requirements, they can be used to judge the adopted panel data for their subsequent use.

In Step 5 and 6 of building the Model, the parameters of the corresponding regression functions are estimated using the methods specified in the Step 5 and 6 i.e. the regression functions for the Fair model are restored by the 2-step least squares method, and the regression functions of the IMF model are restored by the generalized method of moments.

When restoring the developed structures of the Fair model and IMF model, the conditions of the parity of the trade balance elasticities in the nominal exchange rate in the developed Fair model and IMF model are met. These elasticities were taken from [15].

According to Step 7, the parameters of the developed model of Interface 1 were assessed by the ordinary least squares method.

In Step 8, the Model's (1.1) parameters φ_{ij} of Interface 2 were estimated by the method proposed in [2].

In Step 9, the building of the Model is carried out using the developed Fair model, the IMF model, and models of Interface 1 and 2 for further launching by programming.

The hybrid model built using this algorithm consists of 2 blocks: the Fair block, which describes the functioning of the relevant sectors (i.e., households, firms, financial sector, government and the external sector, without the exchange rate formation process) and the IMF model block, which describes the formation of effective equilibrium exchange rates of national currencies based on the output data generated by the second interface of the Fair model block. The obtained estimates of the equilibrium exchange rates from the IMF model block are transmitted using the first interface to the input of the Fair model block.

The Hybrid Model describes the interacting major economies of 44 countries, taking into account the exogenous impact of the indicators of the economies of the other 18 countries and the rest of the world.

Real and nominal GDP, GDP at purchasing power parity, state budget deficit, government debt, nominal exchange rate of the national currency against the US dollar, short-term and medium-term interest rates in the country, the rate of 3-month US Treasury bonds, unemployment rate, consumer price inflation, prices of export and import products in the country, world price for crude oil, fiscal position normalized to nominal GDP, relative income in relation to other countries, the terms of trade of the country, and many other variables are the main endogenous variables of the hybrid Model.

Real government consumption, indirect tax rate, effective corporate and individual income tax rates, effective import duty rate, Central Bank foreign exchange reserves and many other variables are the main exogenous variables of the hybrid Model.

3. TESTING THE MODEL FOR PRACTICAL APPLICATION

Testing the Model for possible practical application, i.e., testing the Model for the conditions of the possibility of transferring the results from computational experiments into the subject area was done by:

1) testing within the stages of building and developing the Model (including building and development of the Fair model, the IMF model and the first interface model) at the level of time series testing and regression functions;

2) testing of the built Model within the framework of the Cowles Commission approach [9];

3) testing of the built Model within the framework of parametric control theory.

The testing of time series and regression functions, respectively, was reduced to

- testing on outliers, level shifts and seasonality in time series, as well as cleaning of these components;

- evaluation of significance of the regression functions' variables; significance of the regression function itself. This involved testing the following - the autocorrelation of regression residuals; the normality of the regression residual distribution; the stability of regression function parameters, and also the verification of coincidence of signs of regression function coefficients with the macroeconomic theory provisions; the over-identifying restrictions for the selected 2 least square method tools (eliminating the bias of the parameter estimation) and the conditions of the rational expectations hypothesis [8,18].

While testing the time series and regression functions, we were able to establish the following. Out of the tested time series containing 4955, seasonality was revealed in 3235, while outliers were identified in 564 we identified outliers. The analysis of the results of the regression function testing (total of 2118) demonstrated their ability to be used as components in the Model.

Testing the Model within the framework of the Cowles Commission approach was carried out by estimating the signs of changes in a number of endogenous variables of the Model when conducting a scenario with changes in some exogenous parameters and checking the compliance of these signs with the main provisions of macroeconomic theory.

Table 3.1 below presents the results of estimating the impact of a 10 percent increase in the values of these exogenous variables on total GDP at purchasing power parity in the period 2015-2020 compared to the baseline forecast using the example of three countries: the Republic of Kazakhstan (RK), the Russian Federation (RF) and the Republic of Belarus (RB). Here, the baseline prediction was obtained using the Model calculations, the exogenous variables of which were predicted using autoregressive models.

Since some of the variables in the basic version of the Model indicated in Table 3.1 are endogenous (i.e., nominal exchange rate, short-term interest rate, export price, import price, world crude oil price, and rate of 3-month us Treasury bonds), they were exogenized in advance respectively, by disabling the corresponding equations of the Model describing the dynamics of these variables.

Table 3.1. Changes in total GDP at PPP in the period 2015-2020 with an increase in the value of the exogenous variables by 10 percent in the same period (as a percentage compared with the baseline calculation)

Exogenous variable	Country		
	RK	RF	RB
Real government consumption in the country	1.32	0.83	0.35
Indirect tax rate in the country	-0.34	-0.41	-0.05
Personal income tax rate in the country	-0.11	-0.20	-0.02
Nominal exchange rate in the country	1.66	1.41	0.39

Short-term interest rate in the country	-0.44	-0.28	-0.06
Export prices in the country	-1.85	-0.88	-2.16
Import prices in the country	0.30	1.02	-0.30
World crude oil price	0.92	0.23	-0.02
Rate of 3-month US Treasury bonds	-0.15	-0.12	-0.09

As can be seen from Table 3.1, the real growth of the Belarusian economy, unlike the cases of Kazakhstan and the Russian Federation, negatively reacts to the increase in import prices. The analysis of the transmission of changes in import prices on real GDP and the resulting changes in other endogenous variables in the Model showed the following. The increase in import prices leads to an increase in the level of consumer prices and the GDP deflator, which eventually increased by 8.04 and 7.00 percent, respectively. An increase in the level of consumer prices directly reduces household consumption and increases the short-term interest rate. An increase in the short-term interest rate leads to an increase in the medium-term interest rate. Growth of the medium-term interest rate directly reduces household consumption and investment in fixed capital in the country. A decrease in household consumption and investment in fixed capital negatively influence the value of domestic sales. The decline in domestic sales as a representative of domestic demand in the country leads to a decrease in real GDP. On the other hand, the increase in import prices leads to a decrease in real imports, which eventually decreased by 1.04 percent. However, this did not improve the situation of the trade balance, as real exports in Belarus also fell by 1.03 percent. Real exports fell for the following reason: an increase in the GDP deflator leads to an increase in export prices (which amounted to 2.77 percent). The growth of export prices leads to a fall in real exports due to the loss of price competitiveness. As a result, the trade balance fell by more than 1.00 percent, and household consumption and fixed investment fell by 0.13 and 0.10 percent, respectively, which led to a drop in real GDP by 0.30 percent.

The analysis of the signs given in Table 3.1 of the values shows that they correspond to the main provisions of macroeconomic theory.

Testing within the framework of parametric control theory was carried out by evaluating the values of the mapping stability indicators that convert the values of exogenous variables of the Model into the values of its endogenous variables [1]. The stability indicator $\beta_f(p,\alpha)$ defined by the Model of the mapping $f: A \to B$ at point $p \in A$ and for selected positive number α is the diameter of the image (with mapping f) of the ball of radius α and the center at point p (in percentage deviations). If for all points $p \in A$ the numerical estimate of $\beta_f(p) = \lim_{\alpha\to 0}\beta_f(p,\alpha)$ is evenly close to zero, then the mapping f, given by the Model under study is estimated on the set A as continuously dependent on exogenous values. In experiments with the Model, a ball with a center at point p corresponding to the baseline values of the following exogenous variables was considered as the set A that belong to the selected region for 2015–2020- government consumption, indirect tax rate (VAT and excise), individual income tax rate, and Central Bank currency reserves. Possible values of all endogenous variables belonging to the same region for 2015-2020 were considered as set B. Estimates of some indicators of stability $\beta_f(p,\alpha)$, obtained using the Monte Carlo method are given in the following Table 3.2. These estimates are obtained by specifying 1000 pseudo-random points xi evenly distributed in a ball of radius α with center at point p and determining the percentage deviations of the coordinates of their images $f(x_i)$ from the corresponding coordinates of point $f(p)$.

In the case of assessing the stability indicator for the entire EAEU, the values of the input factors in the specified set were simultaneously perturbed for all the EAEU countries. Stability indicator values are calculated on the basis of all endogenous variables of EAEU countries.

The analysis of the testing results by the above methods shows the feasibility of using the Model for short-term and medium-term forecasting, for macroeconomic analysis, and for assessing the effective versions of economic policies.

Table 3.2. Stability indicator values $\beta_f(p,\alpha)$ for different values of the radius of the ball α

Region	Radius α of the ball	Value of $\beta_f(p,\alpha)$
EAEU	1.0000	0.0037
EAEU	0.5000	0.0013
EAEU	0.2500	0.0005
EAEU	0.1250	0.0003

4. SOLVING PARAMETRIC CONTROL PROBLEMS ON THE BASIS OF THE MODEL

In this section, GDP per capita at purchasing power parity is taken as the main criterion for various extreme parametric control problems at the levels of individual countries and their groupings.

Figure 4.1 presents the results of the comparative analysis of the GDP per capita in purchasing power parity terms on the average over the period 2015-2020 for a number of countries whose economies are described in the Model.

The analysis of Figure 4.1 demonstrates that in the period 2015-2020, among the countries which are considered in the Model, the highest living standards will remain in the European Union countries (Norway being the forerunner, followed by Ireland, etc.) and in the USA. The countries with the lowest quality of life include Kyrgyzstan, Syria, Pakistan and India. The gap between the richest and the poorest countries, even in the considered sample of the Model, is more than 60.00 thousand international US dollars. The average value of the first 22 countries is about 49.02 thousand international US dollars, while the average of the remaining countries is about 15.96 thousand international US dollars (i.e., the gap is approximately 33.06 thousand international US dollars). Compared with the period of 2010-2014, this gap amounted to 28.00 thousand US dollars, which indicates the aggravation of the problem of convergence of countries in this indicator.

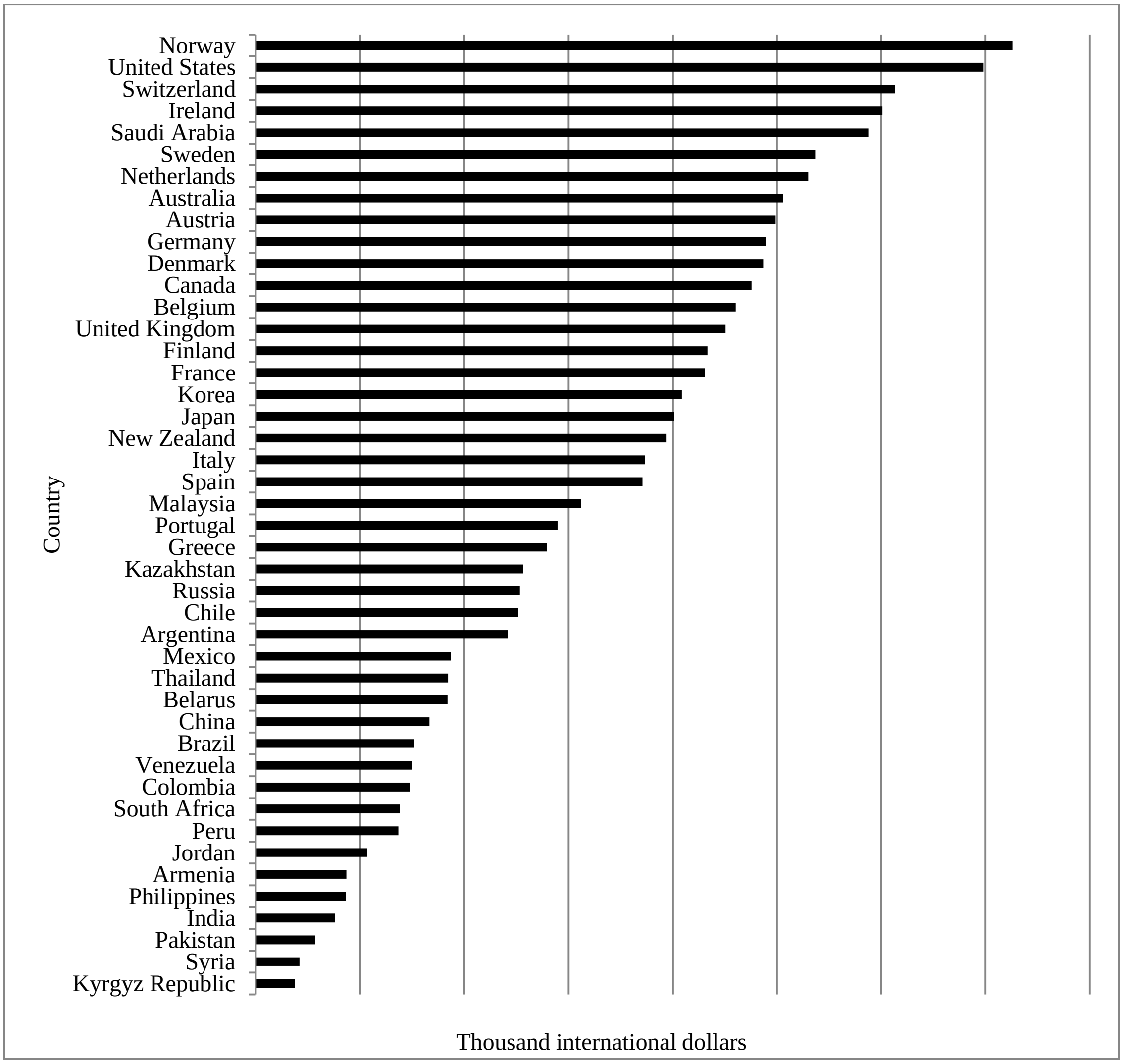

Fig. 4.1. GDP per capita in PPP terms in 44 countries in the Model

The Model calculations (which are close to the IMF WEO October 2017 forecasts) showed that, in addition to the problem of convergence in terms of the adopted poverty indicator, low growth in the world economy and slow growth in world trade (see Figure 4.2) are challenges that need to be faced by the international community.

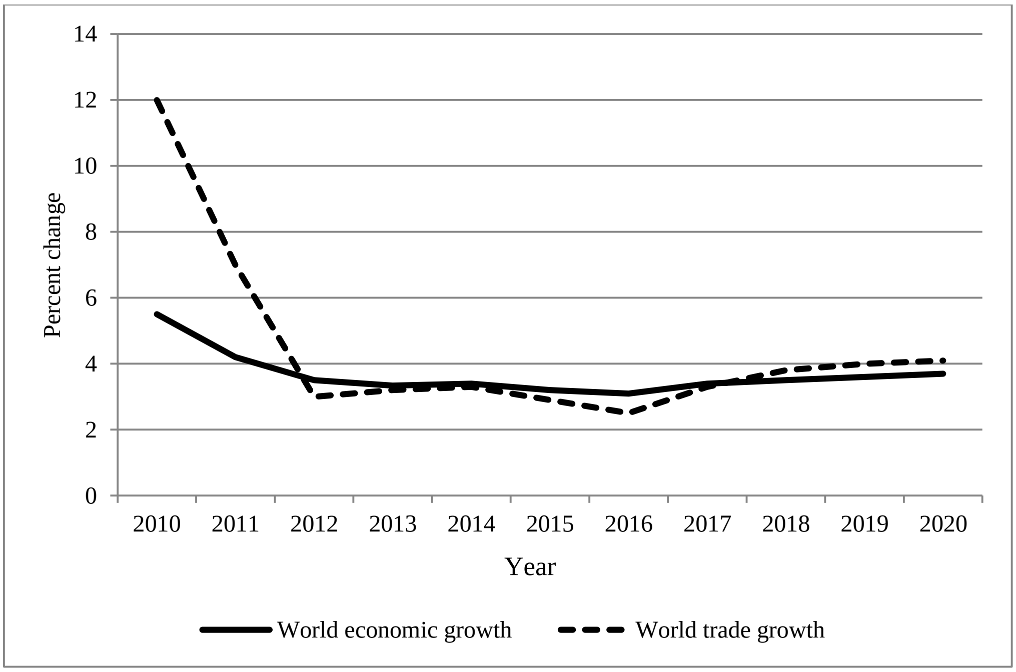

Fig. 4.2. Estimated values (ex-post and ex-ante analysis) of global economic growth and growth of world trade based on the Model (year to year)

Based on the Model and parametric control theory, a number of extreme problems for maximizing GDP per capita at purchasing power parity were formulated and solved, taking into account the results of the analysis of Figures 4.1 and 4.2. Problem 4.1 is the extreme problem at the country level, Problem 4.2 is the extreme problem of coordinated parametric control at the level of the selected set of countries, and Problem 4.3 is the extreme problem of coordinated parametric control at the level of the 5 countries of the EAEU, taking into account the condition of convergence of GDP per capita at the PPPs of these countries. The extreme problem at the country level has the following form:

Problem 4.1. Based on the Model for a given country i ($i \in \{1, \dots, 44\}$) and taking into account the adopted monetary policy in each country, to find the values of the monetary policy instruments ($RS_i(T)$) and fiscal policy ($G_i(T)$, $TaxR1_i(T)$, $TaxR2_i(T)$, $TaxR3_i(T)$), where $T \in \{2015, \dots, 2020\}$, providing the criterion maximum:

$$K_i^1 = \sum_{T=2015}^{2020} YPPP_i(T), \tag{4.1}$$

under restrictions ($T \in \{2015, \dots, 2020\}$):

$$\begin{gathered} |RS_i(T) - \overline{RS_i}(T)| \leq 0.1 \times \overline{RS_i}(T), \\ |G_i(T) - \overline{G_i}(T)| \leq 0.1 \times \overline{G_i}(T), \\ |TaxR1_i(T) - \overline{TaxR1_i}(T)| \leq 0.1 \times \overline{TaxR1_i}(T), \\ |TaxR2_i(T) - \overline{TaxR2_i}(T)| \leq 0.1 \times \overline{TaxR2_i}(T), \\ |TaxR3_i(T) - \overline{TaxR3_i}(T)| \leq 0.1 \times \overline{TaxR3_i}(T), \\ YPPP_i(T) \geq \overline{YPPP}_i(T). \end{gathered} \tag{4.2}$$

In addition, for the EAEU countries ($i \in \{1, \dots, 5\}$), additional restrictions of sustainable growth are used:

$$\begin{gathered} PI_i(T) \leq \min_{r \in \{1,\dots,5\}} PI_r(T) + 0.05, \\ GDEF_i(t) \leq 0.03 * Y_i(t) * PY_i(t), \end{gathered} \tag{4.3}$$

$$GDEBT_i(t) \leq 0.5 * Y_i(t) * PY_i(t).$$

Here, T is the number of the year, $YPPP_i(T)$ is the GDP per capita at PPP, $RS_i(T)$ is the short-term annual interest rate, $G_i(T)$ is government consumption, $TaxR1_i(T)$ - effective corporate income tax rate, $TaxR2_i(T)$ - effective individual income tax rate, $TaxR3_i(T)$ - effective import duty rate, $PI_i(T)$ - inflation of consumer prices; $YP_i(T)$ – nominal GDP in national currency; $GDEF_i(T)$ – state budget deficit in national currency; $GDEBT_i(T)$ - the size of public debt in national currency. The symbol $\bar{}$ corresponds to the basic calculation of the specified variable.

In this problem, the choice of restrictions on the changes of instruments within 10% relative to their baseline values was made for reasons of clarity in order to demonstrate the possibility of solving problems with similar restrictions. As the limitation intervals increase, the optimal value of the criterion of the corresponding problem can only increase, but the risk associated with the adaptation of the economy and society to more significant changes in fiscal and monetary policy (which is not covered by the model) also increases. In the case of the practical implementation of the proposed approach to develop recommendations for conducting macroeconomic policy, the limitations of extreme problems are subject to agreement with the decision maker.

The problem of coordinated parametric control at the level of a selected set of L countries with the numbers $i = 1, \dots, L$ is formulated as follows.

Problem 4.2. For the selected set of $L \in \{2, \dots, 44\}$ countries based on the Model and taking into account the adopted monetary policy in each country, to find the values of the monetary policy instruments ($RS_i(T)$) and fiscal policy ($G_i(T)$, $TaxR1_i(T)$, $TaxR2_i(T)$, $TaxR3_i(T)$), where $T \in \{2015, \dots, 2020\}, i \in \{1, \dots, L\}$ providing the criterion maximum:

$$K_L^2 = \sum_{i=1}^{L} \sum_{T=2015}^{2020} YPPP_i(T) \,, \tag{4.4}$$

with restrictions (4.2) for all countries of this set and restrictions (4.3) for EAEU countries from this set.

Here, in the case of $L = 5$, the specified set of countries is the EAEU; in the case of $L = 44$, the specified set of countries is considered quasi for the world economy.

Problem 4.3. For the selected set of $L = 5$ of the EAEU countries based on the Model and taking into account the adopted monetary policy in each country, to find the values of the monetary policy instruments ($RS_i(T)$) and fiscal policy ($G_i(T)$, $TaxR1_i(T)$, $TaxR2_i(T)$, $TaxR3_i(T)$), where $T \in \{2015, \dots, 2020\}, i \in \{1, \dots, 5\}$, providing the criterion maximum:

$$K^3 = \sum_{i=1}^{5} \sum_{T=2015}^{2020} \left(YPPP_i(T) - \beta \varepsilon_i \left(\frac{YPPP(T) - YPPP_i(T)}{YPPP(T)} \right)^2 \right), \tag{4.5}$$

with restrictions (4.2), (4.3). Here, $YPPP(T)$ – is the aggregated GDP per capita at PPP of the EAEU countries, ε_i is the adjustable weights of the countries, and β is the adjustable weight of the component responsible for the convergence in the criteria.

The use of the empirical model (1.1) allows transforming the growth rates of GDP per capita at PPP in each of the reviewed countries to the corresponding rates of change in the poverty level (the proportion of the population living below the poverty line) obtained as a result of solving the formulated Problems 4.1-4.3. The World Bank's Gini index estimates for the EAEU countries were used (link). Some results of solving the above formulated extremal problems are presented in Table 3 (in percentage changes of the specified indicators of the country on average for the period 2015–2020 as a result of solving the problem compared to the baseline calculation). Here, GDP means the GDP at PPP per capita and convergence -

indicator $\left(\frac{YPPP(T)-YPPP_i(T)}{YPPP(T)}\right)^2$, participating in the definition of the criterion (4.5). The country codes in Table 4.1 are the following: KZ - Kazakhstan, RU - Russian Federation, BY - Belarus, KG - Kyrgyzstan, AM - Armenia, PA - Pakistan and ID - India.

Comparative data analysis on the example of the EAEU countries shows that the effectiveness of coordinated optimization measures aimed at maximizing the sum of the criteria of effectiveness of the functioning of the countries of this regional union is higher than the effectiveness of the same measures of each individual EAEU country. Analysis using the example of India and Pakistan also shows that the effectiveness of coordinated optimization measures aimed at maximizing the sum of performance criteria of the country groupings functioning is higher than the effectiveness of the same measures of a particular country within these groupings.

It should be noted that for the EAEU countries, the effectiveness of measures for coordinated optimization at the level of the quasi-world economy is higher than at the level of the regional union. In addition, the results of solving Problem 4.3 in Table 4.1 show that monetary, exchange rate and fiscal policy measures provide a noticeable convergence of GDP per capita at PPPs of the five EAEU countries.

Table 4.1. Percentage change in indicators compared with the baseline forecast as a result of solving parametric control problems

Problem	Indicator	Country						
		KZ	RU	BY	KG	AM	PA	ID
4.1	GDP	2.99	2.63	2.00	0.69	2.04	1.15	2.33
4.1	Poverty	-10.6	-5.9	-7.7	-2.5	-5.6		
4.2 (L = 5)	GDP	3.75	2.65	5.68	0.96	2.64	-	-
4.2 (L = 5)	Poverty	-13.3	-6.0	-22.0	-3.4	-7.2		
4.2 (L = 44)	GDP	6.93	5.84	7.37	1.95	4.02	2.86	3.93
4.3	GDP	2.99	2.63	5.78	1.62	3.46	-	-
4.3	Convergence	-1.03	-0.31	-2.13	-0.64	-1.21		

The optimal values of economic policy instruments found as a result of solving the corresponding extremal problems were tested for their practical implementation by estimating the values of sustainability indicators for the scenario corresponding to the optimal values of economic policy instruments found. The results of this testing are illustrated below using the example of the scenario obtained as a result of solving Problem 4.2. In assessing the $\beta_f(p,\alpha)$ indicator, the following set of exogenously given parameters for all EAEU countries for 2015–2020 was considered as a vector p. This set includes the following parameters - potential GDP, foreign exchange reserves of the Central Bank, and indicators of government budget accounts. The following endogenous macroeconomic indicators for each EAEU country in the specified period were considered as output variable of mapping f - real GDP, real household consumption, real imports of goods and services, real exports of goods and services, export prices, import prices, GDP deflator, nominal exchange rate of national currency to US dollar, and medium-term interest rate. The results of computational experiments to estimate the sustainability indicators, given below in Table 4.2, show that when the radius α tends to zero with a given pace, the value of the stability indicator tends to zero with the same pace.

Table 4.2. The values of stability indicators within the optimal values of the economic policy instruments that were found from Problem 4.2 with $L = 5$

Radius α of the ball	Value of stability indicator $\beta_f(p,\alpha)$
1.0000	0.0248
0.5000	0.0124
0.2500	0.0062
0.1250	0.0031

Data analysis of Table 4.2 demonstrates the fulfillment of the necessary conditions for the possibility of practical implementation of the results of solving Problem 2.2.

5. CONCLUSION

1. A global multi-country hybrid econometric model was built.
2. Estimates of the necessary conditions for transferring the results of computational experiments based on the Model into the subject domain were obtained.
3. Ex-post and ex-ante state snapshot analysis of the considered economies was carried out.
4. A number of extreme problems aimed at economic growth were formulated and solved, taking into account the conditions of economic convergence. Based on the solutions to these problems, estimates of the rates of change in poverty levels in the respective countries were obtained.
5. The effectiveness of the proposed approaches in evaluating versions of optimal economic policy at the levels of individual countries and their groupings was presented.

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