Modelling the Impact of Institutional Environment on Key Macroeconomic Indicators

Volodymyr Pikhotskyi, Yurii Nikolaienko, Zhanna Derii, Oleksandr Zaitsev, Olha Havryliuk, Iryna Dmytrenko

Abstract: ***The characteristics of the dynamics of the main macroeconomic indicators are important indicators of the state and prospects of the country's economy as a whole. Interest in the study of macroeconomic dynamics is ensured by the uneven growth rates of the main macroeconomic indicators (GDP, consumption, investment) of different countries, as well as the growing lag of the poorest regions of the world from the leading ones in terms of economic development. Existing studies do not fully explain the differences in the behavior of macroeconomic indicators in countries whose economies are comparable for most of the fundamental factors considered. Recently, institutional factors have been used to explain these differences. The insufficient level of development of institutions limits economic growth; this problem is especially relevant in modern countries. Part of the resources is spent on protecting property rights, on overcoming barriers associated with corruption. To overcome the lag in institutional development, it is necessary to identify the mechanism of the influence of institutional parameters on macroeconomic indicators and assess the feasibility of improving various institutions from the point of view of further economic growth.***

The proposed approach to forecasting macroeconomic indicators taking into account the main components of the group of institutional variables can be applied directly in the process of building forecasts. It is also worth noting the proposed method of testing the hypothesis of a better forecast, which allows you to get results that are independent of the specification of the model.

Keywords : Institutional Environment, Impact, Macroeconomic Indicators, Modelling.

I. INTRODUCTION

The characteristics of the dynamics of the main macroeconomic indicators are important indicators of the state and prospects of the country's economy as a whole. Interest in the study of macroeconomic dynamics is ensured by the uneven growth rates of the main macroeconomic indicators (GDP, consumption, investment) of different countries, as well as the growing lag of the poorest regions of the world from the leading ones in terms of economic development.

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A study of the influence of institutional factors on the dynamics of macroeconomic indicators based on the construction of econometric models is presented in the works of D. Acemoglu [1,2], A. Annette, J. Anderson, T. Bac [3], Bondarenko S [4], K. Claug, B. Danylyshyn [5], Z. Derii [6, 7], P. Mauro [8]. An analysis of the channels of influence of individual institutional factors on macroeconomic variables in the form of a theoretical model was implemented in the works of G. Becker, S. Roz-Akkerman, H. Mo, A. Przeworski [9].

The aim of the article is to develop models of economic dynamics that allow for a multi-aspect analysis of the impact of key institutional factors on macroeconomic indicators.

II. MODELING THE IMPACT OF INSTITUTIONAL FACTORS IN FINANCIAL MARKETS ON THE DYNAMICS OF MACROECONOMIC INDICATORS

The influence of socio-political indicators on macroeconomic variables as a whole is widely discussed. The question of such an influence is not called into question - numerous studies show that with the right approach to measuring the various parameters of the socio-economic environment within which the economic system operates, the influence is confirmed. The question is whether it is possible to use a statistically and theoretically substantiated relationship between institutional indicators and macroeconomic phenomena to improve the quality of forecasting the latter.

According to O. Morgenstern [10,11], the forecast of an economic indicator in principle cannot be built on stochastic principles, since economic indicators do not have the necessary statistical properties: the same independent multidimensional distribution. On the other hand, the application of probability theory methods to forecasting economic indicators is substantiated in the works of T. Haavelmo [12,13]. Most modern methods for forecasting economic indicators, including the BoxJenkins technique (ARIMA) and its modifications (ARMAX), take into account stochastic components. The possibilities of such a model are much higher than that of the deterministic approach. The stochastic approach allows you to take into account all the key elements of a number of dynamics of an economic indicator (trend, seasonality, the complex structure of a random component) and is not connected with the rigid structure of the model, for example, it does not require the premise of a monotonic increase / decrease in the amplitude of oscillations. In addition, if necessary, the stochastic model of the dynamics of a macroeconomic indicator can be expanded to include simultaneous dependencies or intertemporal causal relationships with other macroeconomic variables. In practice, it makes sense to use elements of a deterministic trend in the framework of the stochastic model of dynamics if it is traced in the dynamics of the indicator.

The answer to the question of whether the quality of the forecast improves when using socio-political factors was obtained during the experiment, which can be formally described as follows. Let the fact that the dynamics of basic macroeconomic indicators is formed under the influence of the empirical data blocks described above be taken as the initial hypothesis. The first block will include its own lagged values, seasonal components and trend components, the second - other macroeconomic indicators (the list is given below), and the third - socio-political factors. Let two types of forecasts be constructed with the only difference - in the framework of the first type, socio-economic indicators are taken into account, while in the second type the same models are constructed without taking into account socio-economic indicators. The task is to demonstrate a statistically significant excess of the quality of forecasts of the first type over the quality of forecasts of the second type. In accordance with the forecasting paradox [14], in the search for a model that provides the most accurate forecast for a certain period, the use of any criteria for choosing a model is excluded. A model whose maximum lag is selected in accordance with the information criteria of Akaike and Schwartz does not guarantee such a forecast. Similarly, for a model with statistically significant coefficients, it is not a fact that a model with several coefficients of which are statistically insignificant will give a less qualitative forecast. Accordingly, the best model in terms of forecasting (in a certain class) can be said if and only if, within the framework of the class of forecasting models, all possible formulations of the model have been completely enumerated and this model provides the best forecast according to certain criteria. Directional search, with the exception of individual models based on their poor quality of fit, is not suitable for solving this problem. In this regard, two fundamental questions arise: the question of the criteria for the quality of the forecast and the question of a kind of "tree" of various models, the complete passage of which allows you to choose the best model in terms of forecasting in its class.

Within the framework of the experiment, forecasts of the following macroeconomic variables are made:

1. The total final consumption of households according to the SNA methodology.
2. Gross domestic product.
3. The wage fund of wage workers according to the methodology of the SNA.
4. Gross profit in the economy and gross mixed income.
5. Import of goods and services.
6. Export of goods and services.
7. Total tax revenues of the budget of the expanded government.
8. Total expenses of the consolidated budget.

The more serious question is what kind of socio-economic indicators can be used for the experiment. The above review of various indicators and methods for measuring social and economic phenomena allows us to conclude that there are a huge number of them. To make forecasts, it is necessary that the indicator is regularly calculated for the country at least once a year, no later than since 1999. A list of such indicators is divided into groups below (Fig. 1).

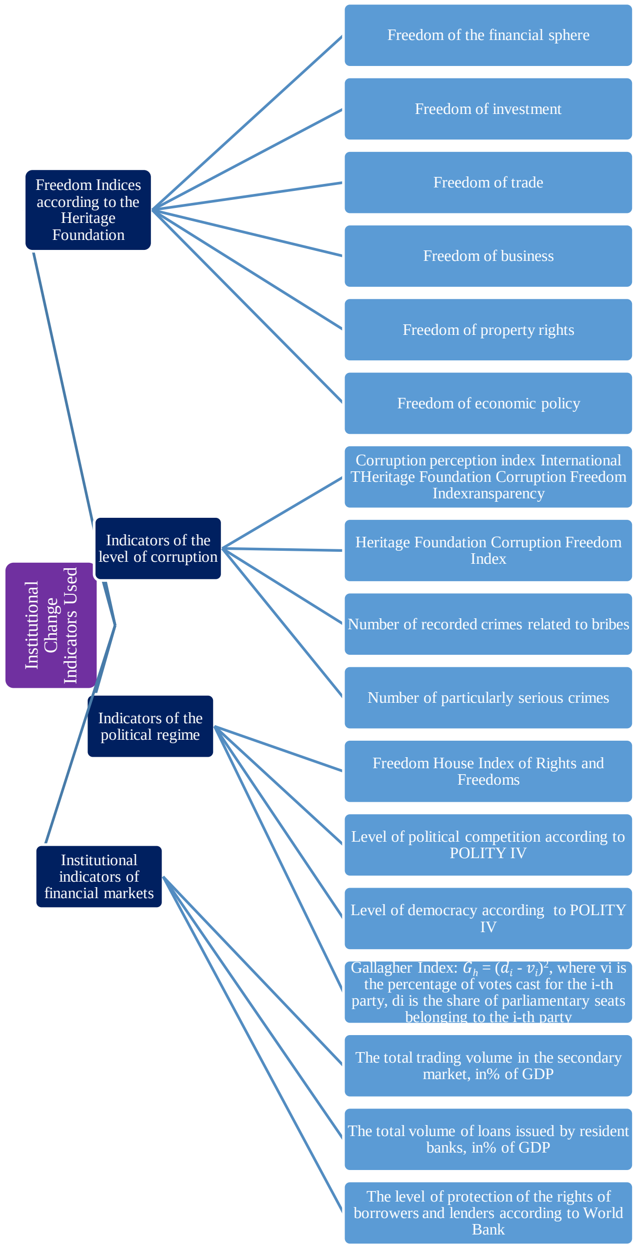

Fig. 1.Institutional Change Indicators Used

The simplest way to choose the best model for predicting a known set of economic indicators is to choose the model that will show the most accurate result on the training sample and, at the same time, a reasonable forecast beyond the sample. The result of such a choice depends on the variety of models considered and on how adequately the quality of forecasts and the presence of statistically significant differences between them were estimated. In addition, the result depends on how consistent the study is.

The quality of forecasts is further evaluated on the basis of indicators such as *the average relative error*, *the average absolute error*, *the square root of the mean square error*, and the *Theil index*.

These indicators are the simplest ways to assess the quality of forecasts. Of particular note is the average relative error, since this indicator does not depend on the units of measurement of the predicted indicators and is easily interpreted: the average forecast error does not exceed MAPE (Mean absolute percentage error). When choosing the best forecast in the future, the main criterion is precisely MAPE. The MARE index is calculated by the formula:

$$MAPE = 100\% \cdot \frac{1}{h}\sum_{i=1}^{h}\left|\frac{f_i - X_{T+i}}{X_{T+i}}\right| \qquad (1)$$

where h is the number of forecast steps, fi is the forecast value, and Xi are the real values of the predicted indicator in the notional future. T denotes the point in time at which the training sample ends. Further, the same notation is used.

The mean absolute error of forecasting (mean absolute error, MAE) is calculated by the formula:

$$MAE = \frac{1}{h}\sum_{i=1}^{h}|f_i - X_{T+i}| \qquad (2)$$

The square root of the root mean square error (RMSE):

$$RMSE = \sqrt{\frac{1}{h}\sum_{i=1}^{h}(f_i - X_{T+i})^2} \qquad (3)$$

The general property of the two indicators of forecast quality indicated above is that they are measured in the same units of measurement as the forecast indicator. This means that, for example, the RMSE indicator itself does not carry any information about the quality of the forecast, but of the two forecasts, the one in which the RMSE indicator is lower is more accurate. MAE has the same property, but is less sensitive to single strong emissions. An important indicator of forecast quality (and also an indicator of whether such a forecasting technique makes sense in principle) are the ratios of RMSE and MAE to similar forecast indicators obtained on the basis of the random walk model:

$$R_{rmse} = \frac{RMSE}{RMSE\,(RW)} \qquad (4)$$

$$R_{mae} = \frac{MAE}{MAE\,(RW)} \qquad (5)$$

The natural analogue of the critical value for both relative indicators is 1, and the result R> 1 means that using such a forecast is basically meaningless, since it is more complicated than the RW forecast by the construction procedure and does not exceed it in accuracy. In the same way, the ratio of the forecast loss function obtained without taking into account institutional indicators is used to the forecast loss function obtained by a similar model taking into account institutional indicators. The last indicator, Theil coefficient (TC), is itself a relative indicator, but its value inversely depends on the units used. In this sense, TC is not such a convenient indicator as MAPE, and can be used either for pairwise comparison of models, or in the form of a relation to the same indicator of RW and RWd (random walk drifted, random walk with shift) forecasts:

$$TC = \frac{\sqrt{\frac{\sum_{i=1}^{h}(f_i - X_{T+i})^2}{h}}}{\sqrt{\sum_{i=1}^{h}\frac{(f_i)^2}{h}} * \sqrt{\sum_{i=1}^{h}\frac{Y_{T+i}{}^2}{h}}} \qquad (6)$$

There are no preferences in the RMSE, MAE, TC group of indicators, all indicators are considered equal when deciding which of the forecasts is better. However, given the number of forecasts evaluated within the framework of the work, it makes sense to abandon those that do not exceed the RW or RWd forecast for each of these indicators. A high-quality forecast should have such properties as bias, the absence of autocorrelation of error, and the absence of a relationship between error and forecast values. Testing is performed using the methods listed below. To test the hypothesis of prediction bias, it is necessary to construct a regression of the forecast error by a constant and estimate the statistical significance of the obtained coefficient using t-statistics corrected for heteroskedasticity and autocorrelation. Standard errors are used in the form of the Newey-West correction (Verbik, 2008), calculated on the basis of the adjusted estimate of the covariance matrix of the form:

$$\hat{V}(\widehat{\beta}) = n(X^T X)^{-1}\left(\frac{1}{\mathrm{T}}\sum_{S=1}^{\mathrm{T}} e_S^2 x_s x_S^T + 1nj=1Lt=j+1nwjetet-jxtxt-jT+xt-jxtT(XTX)-1\right. \qquad (7)$$

The final test is a test for the relationship between forecast error and forecast values. In the framework of the test, a forecast of the forecast errors for the obtained forecasts is built, after which the significance of the regression coefficient is checked in the same way as when checking the forecast for non-bias, with standard errors in the New-West form and additional correction of t-statistics for a fixed forecasting scheme.

The characteristics of the main components obtained are given in the Table 1.

Table- I: The proportions of the dispersion of the main components

The proportion of the dispersion of the components	Block "Freedom"	Block "Policy"	Block "Corruption"	Block "Institutional characteristics of the financial market"
№1	0.42	0.55	0.43	0.54
№2	0.19	0.28	0.38	0.36
Total:	0.61	0.83	0.81	0.90

As can be seen from the table, the use of two main components allows you to take into account more than 80% of the variance of the set of indicators of all blocks, except for a set of indicators of freedom.

In the future, three are used for the block of statistical indicators of freedom, and for the other blocks, the first two main components. According to the results of preliminary testing, government expenditures and tax revenues - TS-series, other macroeconomic indicators - rather DS-series, integrated 1st order. Since there are no economic reasons for the existence of a unit root in the structure of macroeconomic series that are cleared of the trend, the probable reason for this result is the statistically low power of the applied test (extended Dickey-Fuller test) in small samples. The test with an alternative null hypothesis (KPSS test) allows you to recognize all series with the trend clearing stationary. Each model is evaluated without institutional parameters, then with a component of one of the blocks, then with two components of one of the blocks. Excluded from consideration forecasts that:

The forecasts RW and RWd are not superior in terms of accuracy.

1) Recognized biased or ineffective according to test results.
2) Forecasts whose error is autocorrelated are corrected for autocorrelation.

In addition, all forecasts were subjected to a cleaning procedure [13-15]: if the predicted module of the indicator change exceeds all the forecasts observed in the training sample, the value is replaced by the RWd forecast. The main results are shown in the tables below. In the specified table and further in all tables with averaged indicators, the first row is the relative forecast quality according to a fixed scheme, the second - according to recursive schemes (Table 2).

Table- II: RMSE (ARIMA) / RMSE (ARMAX) Ratio

	Im	**Ex**	**C**	**W**	**Pr**	**T**	**G**	**Y**
"Freedom"	1.04	1.03	1.05	1.04	1.05	1.04	1.04	1.03
	1.03	**1.02**	**1.01**	**1.01**	**1.00**	**1.01**	**1.02**	**1.02**
"Policy"	**1.03**	**1.02**	**1.01**	**1.01**	**1.00**	**1.01**	**1.02**	**1.02**
	1.05	1.05	1.04	1.04	1.04	1.03	1.03	1.02
"Corruption"	1.06	1.06	1.06	1.05	1.06	1.080	1.07	1.06
	0.98	**0.99**	**1.01**	**1.00**	**1.01**	**1.00**	**1.01**	**1.03**
"Institutional characteristics of the financial market"	**1.01**	**1.03**	**1.03**	**1.05**	**1.06**	**1.07**	**1.07**	**1.07**
	1.01	1.01	1.01	1.02	1.03	1.03	1.05	1.05

Each element of the table shows the ratio of the average RMSE forecast of the corresponding macroeconomic indicator to the average RMSE of its forecast taking into account a group of institutional factors. Each indicator above unity demonstrates, on average, greater accuracy in forecasts based on institutional indicators.

RMSE (ARIMA) - averaged across all models for each indicator.

RMSE (ARMAX) - averaged over all models and two methods of accounting for blocks: adding one main component and adding two (three for the "freedom" block) main components.

The ratio of the RMSE of the two models that differ only in the set of exogenous factors has a Fisher distribution with a critical value of 1.2, which does not allow us to talk about statistically significant differences between the two methods of forecasting in all cases. However, the use of institutional indicators allows:

- To reduce the forecast error by an average of 4% (MAPE).
- Reduce the overestimated error of the first step of the forecast (forecast for the first quarter of 2012).
- Get rid of autocorrelation of errors of most forecasts. The following problems remain unresolved: • Exogenous institutional factors in the model.
- High average error (7-10%).

The problem of exogeneity is solved by the transition to models of vector autoregression. For each pair of macroeconomic indicator and the first main component of institutional indicators, VAR models are constructed: only with a constant, with a constant and a trend, with a constant, a trend and dummy variables, only with dummy variables. The lag is selected based on the load on each evaluated parameter. In the case of cointegration, VEC-models are used, otherwise - VAR-models in the first differences. The main results are shown in Table 3:

Table- III: RMSE (ARIMA) / RMSE (VAR or VEC) Ratio

	Im	**Ex**	**C**	**W**	**Pr**	**T**	**G**	**Y**
"Freedom"	**0.99**	**1.00**	**1.01**	**1.02**	**1.02**	**1.03**	**1.03**	**1.05**
	1.02	1.02	1.01	1.02	1.03	1.01	1.02	1.02
"Policy"	**1.04**	**1.03**	**1.04**	**1.06**	**1.05**	**1.03**	**1.02**	**1.04**
	1.06	1.06	1.07	1.03	1.06	1.03	1.07	1.02
"Corruption"	**1.07**	**1.08**	**1.06**	**1.07**	**1.05**	**1.06**	**1.06**	**1.05**
	1.08	1.07	1.06	1.06	1.05	1.05	1.06	1.07
"Institutional characteristics of the financial market"	**1.03**	**1.03**	**1.02**	**1.03**	**1.03**	**1.02**	**1.01**	**1.02**
	1.04	1.01	1.02	1.02	1.02	1.01	1.02	1.03

Each element of the table shows the ratio of the average RMSE forecast of the corresponding macroeconomic indicator to the average RMSE of its forecast taking into account a group of institutional factors. Each indicator above unity demonstrates, on average, greater accuracy in forecasts based on institutional indicators.

As is the case with ARIMA models, a statistically significant reduction in the quality of forecasts cannot be obtained. However, the forecast accuracy using institutional indicators is stably higher than the forecast accuracy of the same macroeconomic variable on average for all models. The statistical insignificance of differences can be explained by the equally low quality of forecasts obtained from models with poorly worded statements, regardless of the use/non-use of the main components.

The most obvious increase in forecast accuracy ensures that quantitative indicators of corruption are taken into account, which confirms the view that corruption remains the most significant of all institutional factors for Ukraine. “Political” and “Financial” indicators give a not so significant increase in accuracy.

The experimental results are clearly shown in Fig. 2.

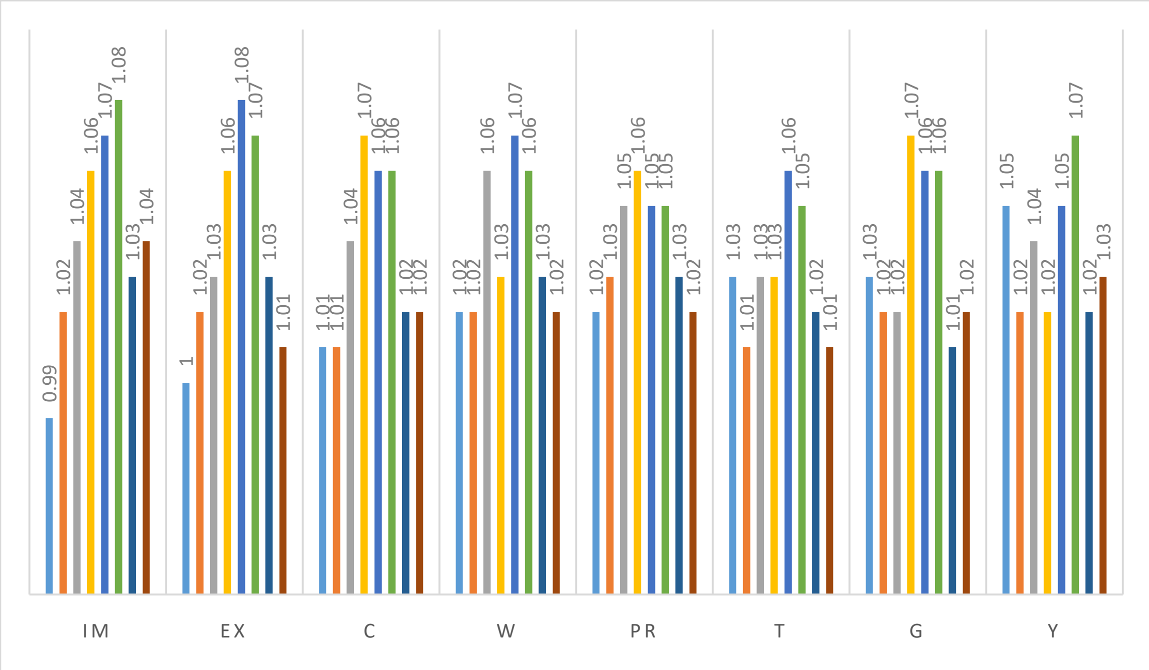

Fig. 2.Experiment Results

III. RESULT AND DISCUSSION

The models developed as part of the study belong to the class of optimization dynamic models, and optimal control methods were used to solve them.

Consider the application of the model on one of the block – Corruption.

Corruption-driven economic growth model

A. The background of the model.

1. Consumers live for two periods, in the first of which are representatives of the "young", in the second - of the "old" generation.

2. Consumers maximize the linear intertemporal utility function, depending on consumption and labor in each period.

3. The manufacturing sector is described by a linear production function.

4. Capital wears out completely in one period.

5. There is a lower permissible limit of consumption, upper and lower permissible limits of labor supply.

6. Income and wages are subject to income taxes; rates are different.

7. Taxes are spent on the production of public goods of exogenously given volume.

8. The bureaucrat maximizes the utility function, which positively depends on corruption income and negatively on moral costs and the expected amount of the fine.

9. The moral costs of the bureaucrat depend on the damage caused to the economy by the activities of the bureaucrat.

10. The bureaucrat has the opportunity to receive corrupt income in two ways - to inflate the value of public goods in order to appropriate surpluses and take bribes to reduce the tax burden.

11. The bureaucrat is risk neutral.

Variables and parameters of the economic growth model taking into account corruption

L1, L2 are the employment of the first and second generation, respectively; *C1, C2* is the consumption of the first and second generation, respectively; *d* substitution of leisure consumption in the second period of the consumer's life; λ - indicator of substitution of leisure consumption in the first period of a consumer’s life; μ - indicator of substitution of leisure consumption in the second period of a consumer’s life; *Cmin* - minimum consumption level; *L1, min, L1, max* - upper and lower employment boundary of the first generation representative; *L2, min, L2, max* - upper lower boundary of employment of a second-generation representative; *w* - salary *r* - gross interest rate; $\tau 1$ - tax rate on labor income of a first-generation representative; $\tau 2$ - tax rate on labor income of a second-generation representative; θ - income tax rate as interest; *S* - total savings; *g* - cost of necessary public goods; *Tfix* - lump-sum tax value; *X* - bureaucrat's illegal income;

dwl - dead weight arising in the economy under the influence of corruption; α - sensitivity of the function of moral goods hacking a bureaucrat to the “dead weight”; *P* - the usefulness of the bureaucrat within one specific period; *p* - the likelihood of detecting corrupt activities of the bureaucrat followed by a fine; *F* - the amount of the fine for corruption.

Statement and solution of the model.

General equations of the model: Representatives of two generations live simultaneously and maximize the linear utility function in the first period of life:

$$u(C,L) = d\left(C_{1,t} - \lambda L_{1,t}\right) + C_{2,t+1} - \mu L_{2,t+1} \quad (8)$$

$$\begin{cases} C_{min} \le C \\ L_{1,min} \le L_1 \le L_{1,max} \\ L_{2,min} \le L_2 \le L_{2,max} \end{cases} \quad (9)$$

Budget constraint in the first period:

$$C_{1,t} + S_t = (w - \tau_{1,t})L_{1,t} \quad (10)$$

in the second period:

$$C_{2,t+1} = (r - \theta_t)S_t + (w - \tau_{1,t})L_{2,t+1} \quad (11)$$

Production function:

$$Y_t = rK_{t-1} + wL_t \quad (12)$$

Budget bureaucrat restriction:

$$g = \tau_{1,t}L_{1,t} + \tau_{2,t}L_{2,t+1} + \theta_t S_t \quad (13)$$

The bureaucrat's utility function:

$$\prod = NPV\ (X - \alpha * dwl(X) - F) \quad (14)$$

where *NPV* is the present value.

Additional condition: total taxes at maximum tax values rates that do not violate consumer decisions are less than the required costs of production public goods.

$$RMSE = \sqrt{\frac{1}{h}\sum_{i=1}^{h}(f_i - X_{T+i})^2} \quad (15)$$

Additionally, the following prerequisites are introduced:

$$g > (w-\lambda)L_{1,max} + (w-\mu)L_{2,max} + (r-d)(\lambda L_{1,max} - C_{min})$$

Additionally, the following prerequisites are introduced: $w > \lambda, w > \mu, r > d$.

B. Model solution

$$u(C,L) = d\left(C_{1,t} - \lambda L_{1,t}\right) + C_{2,t+1} - \mu L_{2,t+1} = u(C,L)$$
$$= d\left(w - \tau_{1,t}\right)L_{1,t} - S_t - \lambda L_{1,t}) + (r - \theta_t)S_t + \left(w - \tau_{2,t}\right)L_{2,t+1} - \mu L_{2,t+1}$$
$$= \left(d\left(w - \tau_{1,t}\right) - \lambda\right)L_{1,t} + (r - \theta_t - d)S_t + \left(w - \tau_{2,t} - \mu\right)L_{2,t+1} \to max$$

$$S_t = \begin{cases}(w - \tau_{1,t})L_{1,t} - C_{min} \\ 0, \end{cases}$$

For lump-sum taxation: $g = T_{fix}, \tau_{1,t} = \tau_{2,t} = \theta t = 0$, respectively

$$L_{1,t} = L1, max, L2, t + 1 = L2, max, C1, t = Cmin, St = wL1, max - Cmin,$$
$$C2, t + 1 = rSt + wL2, t + 1 - g$$
$$Yt = w\,L1, max + L2, max + r\,wL1, max - Cmin$$
$$Ct = Cmin + r\,wL1, max - Cmin + wL2, t + 1 - g$$

In case of commodity taxation, the condition of the impossibility of financing public benefits in sufficient amounts due to non-distorting tax rates applies.

Accordingly, one of the bets must be set at a level higher than the non-distorting one. By default, the bureaucrat sets an overstated rate on the principle of minimal public losses. The value of losses from taxation at a rate higher than optimal is equal to:

1) For the taxation of second-generation income $w - \mu\,(L2, max - L2, min)$

Formed as a reduction in the total value of the wage bill and income of the bureaucrat. The formation of social losses is shown below on the graph of the function of labor supply in the second period (Fig. 3).

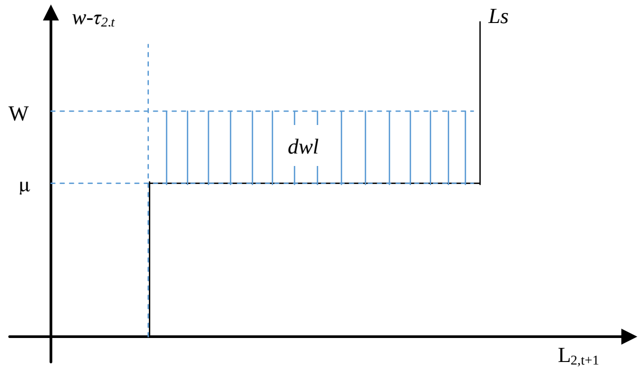

Fig. 3.Graphical solution of the model

This example shows that the proposed model can be used to measure the impact of institutional environment on key macroeconomic indicators.

IV. CONCLUSION

Based on the results of the experiment, the following conclusions can be drawn:

1. The inclusion of the main components of a set of institutional factors in the model improves the quality of the forecast. This result does not depend on the method of assessing the quality of the forecast, the predicted macroeconomic indicator, the method of including the main component in the model (endogenously or exogenously).
2. The block of variables responsible for the level of corruption affects the forecast quality to the greatest extent. To the least extent are indicators of freedom.
3. The effect of the inclusion of institutional factors increases with the complexity of the model.

4. The effect depends on the method of interpolation of institutional indices by quarters. Taking into account the intra-annual trend increases the accuracy of forecasts, which may mean simple synchronization.

5. The results are independent of whether the source macroeconomic variables or their logarithms are used.

6. The results are independent of the basis on which the optimal model lag is determined.

During the experiment it was shown that various groups of institutional factors to varying degrees can improve the quality of the forecast of macroeconomic indicators. The maximum impact was demonstrated by indicators of the level of corruption, relatively high influence was shown by policy indicators (including indicators of the regime of governance) and institutional characteristics of the financial market. Minimal influence is seen from indicators of various kinds of civil and economic freedoms.

The shown dependence of the forecast quality on accounting / non-accounting of institutional indicators is stable and does not depend on the specification of the model. The experiment convincingly shows that a forecast based on institutional characteristics has relatively higher accuracy. The experiment allows us to dwell on one specific method of accounting for institutional indicators, as well as to limit the number of institutional indicators studied. In the future, we will focus only on indicators of corruption, the regime of government, and on the institutional characteristics of the financial market. Also, the index method of measurement allows you to analyze statistical dependencies between institutional variables and macroeconomic indicators, in the future, all institutional changes taken into account are measured using indices.

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