Model for assessing the influence of factors on a country's competitiveness in the global economy

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Abstract. In the work, based on the analysis of the countries-leading competitiveness, it was revealed that all of them among the most developed sectors of the economy had components of the competitiveness index related to innovative development and infrastructure. This suggests that it is the sectors of innovation and infrastructure that can be considered strategically important and make efforts for their development. Therefore, it makes sense to build models related to these areas. The paper presents two macroeconomic models for assessing the influence of factors on competitiveness, one of which will be innovation-oriented, and the second - infrastructure-oriented. These models use spatial data reflecting the assessments of 111 countries for a number of indicators produced by international organizations such as the World Economic Forum, the World Bank, and the World Intellectual Property Organization. Data for the Russian Federation are not included in the sample, since they will be used later to verify the results of the models.

1. Introduction

Building a universal model for assessing the factors influencing a country's competitiveness in the global economy seems impossible due to the complexity and extensiveness of this category. Hence, it will be reasonable to rely on the results obtained earlier in the course of the study. The analysis of the competitiveness leaders in the country revealed that all of them, among the most developed sectors of the economy, had components of the competitiveness index related to innovation development and infrastructure. This is suggestive that the named sectors of innovation and infrastructure can be considered strategically important and worth making efforts for their development. Therefore, it makes sense to build models related to these areas.

Thus, further we shall build two macroeconomic models for assessing the influence of factors on competitiveness. One of the models will be innovation-oriented, and the second model - infrastructure-oriented. They will use spatial data presenting the assessments of 111 countries along a number of indicators produced by international organizations such as the World Economic Forum, the World Bank and the World Intellectual Property Organization. The data concerning the Russian Federation is not included in the sample, since it will be used later to verify the results of the models.

2. Materials and methods

Initially, a wide list of factors related to the selected areas, which could affect competitiveness, was
considered in the study, but only a few turned to be the most significant. Among the indicators selected for the study, the global competitiveness of countries acts as the dependent variable, its data being taken from the Global Competitiveness Index of the World Economic Forum. The indicator will be designated in the model as “GCI”.

Four indicators were selected as independent variables. Among them:
- the index of countries' involvement in global trade, assessing the policies of states and the effectiveness of their institutions in the field of international trade and the development of economic cooperation. The index is calculated by the World Economic Forum, and will be designated in the model as “GET”.
- Global Innovation Index, describing in detail the innovative development of countries in the world being at different levels of economic development. This study is carried out as part of a joint project of the international business school INSEAD, Cornell University, and the World Intellectual Property Organization. This data indicator will be designated in the model as “GII”.
- Global Customs Index, which reflects the effectiveness of customs clearance process carried out by customs control authorities, its speed and simplicity. The index is provided by the World Bank, and will be designated in the model as “CI”.
- The roads quality index, manifesting, respectively, the quality of highways across the world. The index is calculated by the World Economic Forum, and will be designated in the model as “QR”.

Since part of the indicators are issued every two years and the latest publications reflect the situation for the year 2016, all the indicators used were taken during this period, in order to make the sample more representative. In addition, all indicators used are indexed values.

The first of the considered and compared models is the innovative model for assessing the influence of factors on a country's competitiveness in the global economy. It will include the Global Trade Involvement Index (GET), the Global Customs Index (CI) and the Global Innovation Index (GII).

The second one is an infrastructure model for assessing the influence of factors on a country's competitiveness in the global economy. It will include the Global Road Quality Index (QR), the Global Customs Index (CI), and the Global Trade Engagement (GET) Index.

In order to test the conformity, all models will be tested using a number of standard tests which match the selected data type.

Among them:
- test for the significance of the coefficients;
- test for the significance of the regression equation;
- test for the multicollinearity absence;
- tests for heteroscedasticity absence;
- test for specification.

The models are built in the program Gretl.

### 3. The study of the country's competitiveness with application of economic and mathematic modelling

Model 1: OLS, applied observations 1-111
Dependent variable: GCI

|         | Coefficient | Statistic error | t-statistics | P-value  | Significance level |
|---------|-------------|-----------------|--------------|----------|--------------------|
| const   | 1.73032     | 0.225583        | 7.670        | 8.39e-012| 0.01               |
| GET     | 0.205948    | 0.0861062       | 2.392        | 0.0185   | 0.05               |
| GII     | 0.0308523   | 0.00473660      | 6.514        | 2.46e-09 | 0.01               |
| CI      | 0.199602    | 0.0797524       | 2.503        | 0.0138   | 0.05               |

The main data for the model:
Average of the dependent variable - 4.436847
Stat. deviation of the dependent variable - 0.646154
Sum of the residuals sq. - 6.836329
Statistic error of the model - 0.252767
Square- R - 0.851147
Corr. Square- R - 0.846973
F(3, 107) - 203.9427
P-value (F) - 4.25e-44
Logical likelihood - -2.808171
Akaike Criterion - 13.61634
Schwarz Criterion - 24.45446
Hennan-Quinn Criterion - 18.01305

Addition of robust standard errors introduced alteration in the model, thus raising the significance of the factors. Let us designate the acquired model with robust standard errors as Model 1.1.

Table 2. Model 1.1 OLS for variables GET, GII, CI with robust standard errors.

| Coefficient | Coefficient | Statistic error | t-statistics | P-value | Significance level |
|-------------|-------------|-----------------|--------------|---------|-------------------|
| const       | 1.73032     | 0.224027        | 7.724        | 6.41e-012 | 0.01 |
| GET         | 0.205948    | 0.0861062       | 2.608        | 0.0104  | 0.05 |
| GII         | 0.0308523   | 0.00460764      | 6.696        | 1.02e-09 | 0.01 |
| CI          | 0.199602    | 0.0692875       | 2.881        | 0.0048  | 0.01 |

The main data for the model:
Average of the dependent variable - 4.436847
Stat. deviation of the dependent variable - 0.646154
Sum of the residuals sq. - 6.836329
Statistic error of the model - 0.252767
Square- R - 0.851147
Corr. Square- R - 0.846973
F(3, 107) - 253.7765
P-value (F) - 1.75e-48
Logical likelihood - -2.808171
Akaike Criterion - 13.61634
Schwarz Criterion - 24.45446
Hennan-Quinn Criterion - 18.01305

Testing of the model 1.1:
The significance of the regression equation test:
H0: the equation is not significant, F calc. < F crit.
The critical value of Fisher statistics is 2.68869. F calculated is 253.7765, hence F calc. > F crit., H0 deviates.
Conclusion: the equation is significant.
Multicollinearity absence test:
H0: multicollinearity is absent.
Method of inflationary factors:
Minimum Possible Value = 1.0
Values> 10.0 may indicate the presence of multicollinearity:
GET - 5.479
GII - 5.456
CI - 3.932
All considered values are less than 10, therefore, multicollinearity is absent.
Heteroscedasticity absence tests:
White test for heteroscedasticity -
Zero hypotheses: heteroscedasticity is absent.
Test Statistics: \( LM = 6.09161 \)
p-value = \( P \left( \chi^2 (9) > 6.09161 \right) = 0.730716 \)
p-value > \( \alpha (0.05) \), therefore, \( H_0 \) is accepted, heteroscedasticity is absent.

Breusch-Pagan test for heteroscedasticity -
Zero hypotheses: heteroscedasticity is absent.
Test Statistics: \( LM = 3.6598 \)
p-value = \( P \left( \chi^2 (3) > 3.6598 \right) = 0.30062 \)
p-value > \( \alpha (0.05) \), therefore, \( H_0 \) is accepted, heteroscedasticity is absent.
Both tests confirm the absence of heteroscedasticity.

Model Specification Test:
Ramsey Test (RESET) (squares and cubes)
Test statistics: \( F = 1.695309 \),
p-value = \( P \left( F (2.105) > 1.69531 \right) = 0.189 \)
Ramsey Test (RESET) (squares only)
Test statistics: \( F = 0.033185 \)
p-value = \( P \left( F (1.106) > 0.0331848 \right) = 0.856 \)
Ramsey test (RESET) (cubes only)
Test statistics: \( F = 0.071104 \)
p-value = \( P \left( F (1.106) > 0.0711038 \right) = 0.79 \)
In all three versions, the p-value > \( \alpha (0.05) \), therefore, the specification is correct.

Test for normal probability of residuals:
Test for normal error distribution -
Zero hypotheses: errors are distributed according to the normal law
Test Statistics: \( X^2 (2) = 2.67478 \)
p-value = \( 0.26253 \)
p-value > \( \alpha (0.05) \), therefore, the residuals are normally distributed.

Model 1.1 has passed all tests, therefore, it can be considered adequate and fair, and be used in the future. Since, in this case, the work is carried out not with time series, but with spatial data, it is difficult to make a forecast for future periods, so it makes sense to do the following:
The model contains data for a number of countries, but the data for Russia has not been included; therefore, based on its data for selected independent variables, it is possible to predict the value of the competitiveness index for the period in question and compare the value obtained using the model with the real value. If these values are close to each other, the model will be considered fair.
For Russia, the values of independent variables are as follows:
GET = 3.79
GII = 38.76
CI = 2.01
The equation of the Model 1.1 is as follows:
\[ ^\wedge \text{GCI} = 1.73 + 0.206 \times \text{GET} + 0.0309 \times \text{GII} + 0.200 \times \text{CI} \]
When substituting data for the RF into the equation, we obtain the following:
\[ \text{GCI} = 1.73 + 0.206 \times 3.79 + 0.0309 \times 38.76 + 0.200 \times 2.01 \]
\[ \text{GCI} = 4.110424 \]
The real value of the global competitiveness index for the Russian Federation for the period under review equals to 4.5. It follows that if the main role in the global competitiveness index is played by indicators related to the level of development of innovations, involvement in global trade and the development of customs structures, Russia would have received a lower rating (the deviation was 0.389576).

Table 3. Model 2 OLS for the variables GET, GII, CI.
Coefficient | Statistic error | t-statistics | P-value | Significance level
---|---|---|---|---
const | 0.885249 | 0.202630 | 4.369 | 2.90e-05 | 0.01
QR | 0.104151 | 0.0424603 | 2.453 | 0.0158 | 0.05
CI | 0.304350 | 0.0925836 | 3.287 | 0.0014 | 0.01
GET | 0.492348 | 0.0816134 | 6.033 | 2.35e-08 | 0.01

The main data for the model:
- Average of the dependent variable - 4.436847
- Stat. deviation of the dependent variable - 0.646154
- Sum of the residuals sq. - 9.038764
- Statistic error of the model - 0.290645
- Square- R - 0.803191
- Corr. square- R - 0.797673
- F (3, 107) - 145.5582
- P-value (F) - 1.27e-37
- Logical likelihood - \(-18.30775\)
- Akaike Criterion - 44.61549
- Schwarz Criterion - 55.45362
- Hennan-Quinn Criterion - 49.01220

Addition of robust standard errors has introduced no significant alterations in the model, thus it is possible to proceed with testing of the Model.

The test for the significance of the regression equation:
- \(H_0: \text{the equation is not significant, } F \text{ calc. } < F \text{ crit.}\)
- The critical value of Fisher statistics is 2.68949. \(F \text{ calculated} = 145.5582\), therefore \(F \text{ calc. } > F \text{ crit.}, H_0 \text{ deviates.}\)

Conclusion: the equation is significant.

The multicollinearity absence test:
- \(H_0: \text{multicollinearity absence.}\)
- Method of inflationary factors:
- Minimum Possible Value = 1.0
- Values > 10.0 may indicate the presence of multicollinearity:
  - QR 2.748
  - CI 4.008
  - GET 3.722
- All considered values are less than 10, therefore, multicollinearity is absent.

The heteroscedasticity absence tests:
- White test for heteroscedasticity -
  - Zero hypothesis: absence of heteroscedasticity
  - Test Statistics: \(LM = 9.99014\)
  - \(P\)-value = \(P(\chi^2(9) > 9.99014) = 0.351284\)
  - \(P\)-value > \(\alpha (0.05)\), therefore, \(H_0\) is accepted, heteroscedasticity is absent.
- Breusch-Pagan test for heteroscedasticity -
  - Zero hypotheses: heteroscedasticity is absent.
  - Test Statistics: \(LM = 5.71679\)
  - \(P\)-value = \(P(\chi^2(3) > 5.71679) = 0.126232\)
  - \(P\)-value > \(\alpha (0.05)\), therefore, \(H_0\) is accepted, heteroscedasticity is absent.

Model Specification Test:
- Ramsey Test (RESET) (squares and cubes)
  - Test statistics: \(F = 1.822108\)
  - \(P\)-value = \(P(F(2,105) > 1.82211) = 0.167\)
- Ramsey Test (RESET) (squares only)
Test statistics: $F = 3.668364$, 
$p$-value = $P \left( F \left( 1.106 \right) > 3.66836 \right) = 0.0581$
Ramsey test (RESET) (cubes only)
Test statistics: $F = 3.640989$,
$p$-value = $P \left( F \left( 1.106 \right) > 3.64099 \right) = 0.0591$.
In all three variants, $p$-value $> \alpha$ (0.05), therefore, the specification is correct.
Test for normality of residuals:
Test for normal error distribution -
Zero hypotheses: errors are distributed according to the normal law
Test Statistics: $X$-square $(2) = 0.198037$
$p$-value = 0.905726
$p$-value $> \alpha$ (0.05), therefore, the residues are normally distributed.
Model 2, like model 1.1, has passed all tests and can also be accepted and used further. We proceed with it similarly to model 1.1:
The equation of the model 2 is as follows:
\[ \hat{GCI} = 0.885 + 0.104 \times QR + 0.304 \times CI + 0.492 \times GET \]
RF data for Model 2:
\[ QR = 2.90 \]
\[ CI = 2.01 \]
\[ GET = 3.79 \]
When substituting RF data into the model, we get the following:
\[ \hat{GCI} = 0.885 + 0.104 \times 2.90 + 0.304 \times 2.01 + 0.492 \times 3.79 \]
\[ \hat{GCI} = 3.66232 \]
The real value of the global competitiveness index for the Russian Federation for the period under review comprised 4.5. This means that if the main role in the global competitiveness index was played by indicators related to infrastructure (such as road quality), involvement in global trade and the development of customs structures, Russia would get a much lower rating (the deviation was 0.83768, which is more than twice the deviation of the model 1.1.).

4. Conclusion
Since both models passed all tests and gave adequate results, it makes sense to interpret the coefficients of both models.
Thus, with an increase of the engagement in global trade index by 1 unit, the global competitiveness index will increase by 0.206. This does not contradict logic, since an increase in the efficiency of state institutions in the area of international trade and the development of economic cooperation may cause an increase in trade, which will have a beneficial effect on the country economy, strengthen its position in the world market and, accordingly, increase its competitiveness.
A growth by 1 unit of the global innovation index will increase competitiveness by 0.0309. This is explained by the fact that progress does not stand still, and literally everything from technologies and production tools to documents circulation systems is constantly being upgraded in order to increase efficiency. Not enough attention paid to innovation incurs losses in many areas, and, undoubtedly, it affects competitiveness. If you “have your finger on the pulse” and follow the trends in the field of innovations, the chances are high at least to keep your position even if you do not reach any particular heights in competitiveness.
An increase by 1 unit of global customs index will increase the global competitiveness index by 0.2. This is quite a realistic assessment, since the customs authorities activities are of great importance for competitiveness. Increasing the speed of customs procedures and their simplicity can be the reason for the simplification of foreign economic activity for companies, which will increase both their competitiveness and the competitiveness of the country itself.
And, finally, an increase by 1 unit of the road quality index will increase competitiveness by 0.104. This is explained by the fact that high quality of roads has a beneficial effect on logistics, and,
consequently, the trade, the speed at which goods can be delivered to the addressee. Roads can be compared with blood vessels in the body - if they work efficiently, the “body” develops, if they decline, there is a general decline in health in the body (or, for the country, a decrease in competitiveness).

Speaking about models in general, the conformity of model 1.1 is proved by the previously mentioned findings of the study, from which it follows that countries actively participating in international trade and supplying high-tech products to the global market are considered to be the most competitive.

Model 2, which includes such variables as the global quality of roads index, the global customs index and the index of countries' involvement in global trade, is also quite logical and fair, since the indicators used in it are closely related to the efficiency of international trade logistics and reflect how State infrastructure and policies facilitate unrestricted movement of goods across borders to their destinations. And this, of course, has a strong impact on the global competitiveness of countries.

Thus, the development of these models allowed us to identify the main directions, the development of which can positively affect the level of the global competitiveness of a country. In this connection, they can be used in the development of public policy to determine the priority directions of development.

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