# Gravity-type model of Czech agricultural export

*Gravitační model českého zemědělského vývozu*

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**Abstract:** The article concentrates on the application of gravity-type model to explain the volume of agro-exports from the Czech Republic. The multiplicative exponential function of the appropriate explanatory variables is used to describe the bilateral trade flows. Gross national product, gross national product per capita and geographical distance between the capitals of economies proved statistically significant. From regression analysis of the transformed data, there is apparent the positive correlation between the export volume of the commodity group 0 – Food and live animals SITC, rev.3 and gross national income. On the contrary, the negative correlation is between the agro-export volume and gross national income per capita and geographical distance as well. The built model is significant at the 5% level and explains more than 75% of dependent variable variance.

**Key words:** international trade, agricultural trade, log-linear regression, trade flows

**Abstrakt:** Příspěvek se zabývá aplikací gravitačního modelu na vysvětlení velikosti exportů zemědělských komodit z České republiky. Závislost objemu bilaterální obchodní výměny na příslušných vysvětlujících proměnných je popsána multiplikativní exponenciální funkcí. Z použitých vysvětlujících proměnných se jako statisticky významné prokázaly hrubý národní důchod, hrubý národní důchod na obyvatele a geografická vzdálenost měřená mezi hlavními městy. Z provedené regresní analýzy na transformovaných datech vyplývá pozitivní závislost objemu exportu komoditní třídy 0 – Potraviny a živá zvířata SITC, rev. 3 na hrubém národním důchodu a negativní závislostna hrubém národním důchodu na obyvatele a geografické vzdálenosti. Sestavený model je statisticky významný na hladině 5 % a vysvětluje více než 74 % variability závislé proměnné.

**Klíčová slova:** mezinárodní obchod, zemědělský obchod, linearizování regrese, obchodní toky

## INTRODUCTION

The gravity model declares very good results in empirical studies of bilateral economic relations. The inspiration for the model came from the physical rule of universal gravity. Generally, the strength of mutual relation depends on the dimension of the object and on the attributes of the environment. So simply the larger and closer objects show a more intensive interrelation.

When the model is, by analogy, applied to the trade flow of goods between the countries, it describes the correlation of trade volumes with the size of both economies and "closeness" of the economies. The size or strength of economy is usually characterised by some aggregate product (GNP, GNI, etc), population or product per capita. The objective of the closeness indicator is encapsulation of all obstacles and advantages of mutual trade. The obstacles are hidden in transportation cost (geographical distance is usually the proxy), import and export tariffs, different prices, etc. On the other hand, positive impact on trade flow have common border, common language, membership in trading blocs, complementarity in comparative advantages, the extent of foreign trade investment, etc.

In this paper, Czech agricultural export is analysed from the point of view of the gravity-type model. The main determinants of the gravity model will be derived using the step regression analyses and the multiple regression analyses. The model will be derived from the sample of main trade partners of Czech economy in agricultural commodities. Assuming the results given by the model describe the typical level of Czech agro-trade, we can estimate the potential extent of bilateral trade with the other countries.

The gravity model in its most general formulation explains the bilateral flow $F_{ij}$ from economy $i$ to economy $j$ as a function of a source object $S_i$, destination object $D_j$ and the environment characteristics $E_{ij}$ (Tinberger 1962; Bergstrand 1985). The choice of the particular explanatory characteristics varies highly. Mostly, the gross national product (income) per capita and geographical distance are used (Bergstrand 1985; Porojan 2000). Other research-

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ers explain the trade flows by population, gross national product, commodity prices, real effective exchange rate, foreign direct investments, foreign currency reserves, import tariffs, etc. (Porojan 2000; Feenstra et al. 1999; Markusen et al. 1996; Matyas 1998).

The commonly used equation form is inspired by the Cobb-Douglas production function and is following:

$$F_{ij} = \alpha_0 \times \prod_{k=1}^{n} ( X_k^{\alpha_k} ) \times e^{u_{ij}} \quad (1)$$

where:
$F_{ij}$ – the trade flow from economy $i$ to economy $j$
$X_k$ – the explanatory variable
$\alpha_0$ – the model constant
$\alpha_k$ – model parameter
$n$ – number of explanatory variables
$u_{ij}$ – normal random error term

The equation (1) can be alternatively rewritten in log-linear form to estimate the model parameters using the ordinary least square method. Bilateral trade flows are then given:

$$F_{ij}^* = \beta X + u_{ij} \quad (2)$$

where:
$F^*_{ij}$ – logarithm of trade flow from economy $i$ to economy $j$
$\beta$ – a vector of parameters
$X$ – matrix of logs of explanatory variables
$u_{ij}$ – normal random error term.

The use of ordinary least square method for parameter estimation is often ignoring the prerequisites of the method. The appropriateness of the ordinary least square method is questioned by Anselin (1998). The author proves the presence of spatial effects in the aggregated data. It is namely spatial dependence of residua caused influence of other in the model not involved economies and secondly, spatial heteroskedasticity resulting from the heterogeneity in variables. The application of the ordinary least square method is then misleading.

Anselin et.al (1996), Porojan (2000) suggested two solutions of the problem of spatial correlation. Firstly to estimate, instead of the equation (2), the following equation:

$$F_{ij}^* = \beta X + \rho W F_{ij}^* + v_{ij} \quad (3)$$

where:
$F^*_{ij}$ – logarithm of trade flow from economy $i$ to economy $j$
$\beta$ – a vector of parameters
$X$ – matrix of logs of explanatory variables
$\rho$ – spatial autocorrelation coefficient
$W$ – matrix of coefficients of bilateral influence of economies
$v_{ij}$ – normal random error term.

The matrix $W$ can be constructed in more different ways. In literature, there is used the specification based on neighbouring economies. Mostly there prevails the standardized contiguity matrix. Its elements are defined as follows:

$$w_{ij} = w_{ij}^* / \sum_j w_{ij}^* \quad (4)$$

where
$w_{ij}$ – element of matrix $W$
$w^*_{ij}$ – 1 for contiguous countries and 0 for the others.

Secondly, the impact of spatial dependence can be decreased by adding the dummy variables among the explanatory variables. This way the influence of membership in trading blocs or presence of common language, historical relations (e. g. former colony) explains part of the bilateral trade flow.

The heteroskedasticity in the data can be removed by Park procedure (Brennan et al. 1987) based on assumption of correlation between residua $e$ and explanatory variables $X_k$ in the form:

$$e^2 = a \times X_k^{2b_k} \quad (5)$$

Rewriting the equation (5) in the log-linear form and applying the ordinary least square method give the estimations of parameters $a$ and $b_k$. Transforming the data by weights $X_k$ ^ $-b_k$ , they become homoskedastic (e.g. Brennan et al. 1987).

Authors usually involve more explanatory variables in the gravity model to prevent the underspecification of the model. The main disadvantage of this approach is very often the increase in multicolinearity, that destroys the estimations as well (Feenstra et al. 1999, 1996; Matyas 1998).

## METHODS AND DATA

The modelling of trade flow will be based on the equation (2), that is the log-linear form of equation (1). To improve the estimation of log-linearised equation, the weighted ordinary least square method that does not give asymptotic biased and consistent estimations of parameters is used. The used weights are square of dependent variable (Seger 1998).

To avoid the underestimating, the larger set of explanatory variables will be used from the beginning. The forward stepwise regression analyses identifies the significant explanatory variables with conjunctive regard to its multicolinearity. The estimations from the ordinary least square method will be verified from the economic and statistical points of view. In the statistical part of model verification, the stress will be laid on tests of heteroskedasticity and multicolinearity. The spatial correlation will be decreased by involving the appropriate dummy variables from the very beginning. All calculations will be done by Unistat 5.1 Data Processor.

Since analysing the trade of Czech economy, the characteristics of the first object – the Czech Republic – are always the same for all bilateral trade flows. Their cumulative impact mirrors in the model constant.

The agro-export is identify as export of commodity group 0 – Food and live animals, Standard International Trade Classification SITC, rev. 3. The data in the territorial structure in USD were collected from the Central Bureau of Customs database, the averages of years 1999–2001 were used to eliminate the year unstability in data.

The set of explanatory variables was made very wide, involving the eight determinants in the following order: gross national income (GNI) per capita in USD computed by the Atlas method (World Bank 2002), gross national income in USD computed by the Atlas method, average import tariff for agricultural products, total imports of manufactured products in USD, real effective exchange rate, two dummy variables describing the membership in the EU or the EFTA and finally the geographical distance between the capitals of the countries. All data were collected from the World Development Indicators 2002 or the World Development Indicators database. The geographical distances were set by the Distance Calculator accessible via http://www.indo.com/distance/.

## RESULTS AND DISCUSSION

The collected data were inserted into the Unistat Data Processor and then appropriate function on their logarithm was applied to. The forward stepwise regression brought the results listed in Table 1.

Table 1. Results of forward step regression

| Step | Variable | $R$-square | $F$-ratio | Significance |
|---|---|---|---|---|
| 1 | GNI per capita | 0.5924 | 47.9682 | 0.0000 |
| 2 | Distance | 0.7324 | 27.5233 | 0.0000 |
| 3 | Real exchange rate | 0.7725 | 18.5693 | 0.0000 |
| 4 | GNI | 0.8045 | 13.5991 | 0.0000 |
| 5 | Population | 0.8152 | 11.0234 | 0.0000 |

Table 2. Summary of regression results

| | Coefficient | Standard error | $t$-value | Significance |
|---|---|---|---|---|
| Constant | 17.7012 | 1.3268 | 13.3408 | 0.0000 |
| GNI per capita | –1.5686 | 0.1732 | –2.6921 | 0.0056 |
| Distance | –1.8354 | 0.2132 | –1.9746 | 0.0285 |
| GNI | 0.2531 | 0.0423 | 1.7707 | 0.0431 |

$R$ squared = 0.7652
$R$ squared adjusted = 0.7425
$F(3.31)$ = 0.0952
Significance $F$ = 0.0379
Durbin-Watson = 1.8648

Conjunctive analyses of the computed matrix of particular correlations proved the hight degree of statistic multicolinearity, especially between the real effective exchange rate and GNI per capita, secondly between GNI and population.

It seems, that the best result should be reached by involving GNI per capita, geographical distance and GNI. The application of ordinary least square method and consequent analyses of residua indicated the heteroscedasticity depending on the GNI. The existence of heterescedasticity was tested by the Spearman test, the Spearman ratio reached the value of 0.8845. The heteroscedasticity was removed by the Park procedure.

The ordinary least square method was applied again on the transformed data. Brief results are presented in Table 2.

The regression analyses of the transformed data explain more than 74% of variance of food export from the Czech Republic using the three explanatory variables. The final model was built on the data with removed heteroscedasticity, the multicolinarity according the comparison of $R$-squared of the total model and $R$-squared of the particular models is not significant. The autocorrelation measured by the Durbin-Watson statistic is positive but not significantly.

The regression analyses resulted in following model of Czech agro-export:

$$\text{export} = e^{17.7012} \times \text{GNI per cap.}^{-1.5686} \times \text{distance}^{-1.8354} \times \times \text{GNI}^{0.2531}$$

where export is in millions of USD, GNI per capita in thousands of USD, distance in kilometers and GNI in millions of USD.

From the economic point of view, the signs of the coefficient are correct. The GNI describes the size of the economy and the correlation should be positive. On the other hand, the geographical distance characterizes the obstacles to trade, its higher value leads to decrease in bilateral international trade. The variable GNI per capita can be interpreted as the level of economic development. Its negative coefficient corresponds with the relative lower competitiveness of Czech export into more developed economies.

Comparing the computed model with other researches, we can learn that exports are usually negatively correlated with the size of the economy (e.g. Matyas 2000). But the size is measured by total population and the negative correlation characterizes greater self- sufficiency of a bigger economy. Other researchers construct model using only two explanatory variables: GNI per capita and distance. (e.g. Porojan 2000; ITC Market Analysis Section 2000) Then GDI per capita characterizes both the level of development and the level of consumption and the correlation with the export volume is positive.

The calculated model explains the bilateral trade volume of the group 0 – Food and live animals, using three explanatory variables. The basic dependency trends correspond with the models of total trade flows. The minor disparity can be given by the different choice of explanatory variables in each of the models.

## REFERENCES


Bergstrand J.H. (1985): The gravity equation in international trade: some microeconomic foundations and empirical evidence. Review of Economics and Statistics, *67*: 474–481.

Brennan M.J., Carroll T.N. (1987): Preface to quantitative economics and econometrics. South western Publishing, Cincinnati.

Feenstra R.C., Markusen J.A., Rose A.K. (1999): Using the gravity equation to differentiate among alternative theories of trade. NBER Working Paper no. 6804.

ITC Market Analysis Section (2000): TradeSim: ITC simulation model for bilateral trade potentials. ITC Backgound Paper, Feb. 2000.

Markusen J.R., Venables A. (1996): The theory of endowment. Intra-industry trade and multinational trade. NBER, Working Paper No. 5529.

Matyas L. (2000):The gravity model: some econometric consideration. World Economy, *21*: 397–401.

Porojan A. (2000): Trade flows and spatial effects: the gravity model revised. Review of University College London, *4*: 168–173.

Seger J., Hindls R., Hronová S. (1998): Statistika v hospodářství. Praha, Manager podnikatel.

Tinberger J. (1962): Shaping the world economy: suggestion for international trade policy. The Macmillan Press, London.

World Bank (2002): World Development Indicators 2002.


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