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Abstract: *The aim of the paper is to propose a new simple frictionless model of international trade shares as an alternative to standard gravity models. In the proposed model (total) shares of export from a given country depend only on a gross domestic product and a distance of importing countries. The model is examined by a linear regression with corrected heteroscedasticity for the latest export data from Germany and the Czech Republic. Results show that the model is very successful in explaining export shares with coefficients of determinacy 0.75 and 0.98 respectively.*

Keywords: export, Czech Republic, Germany, gravity model, international trade.

JEL: C51, F14, F17.

1. Introduction

Recently, a quantitative description of international trade by gravity models of various kinds (with or without frictions, structural or non-structural, etc.) based on Newton's law of gravitation grew on popularity in the literature with some success in explaining empirical data (observed volumes of trade among countries). The gravity model for international trade was used for the first time by Tinbergen (1962), and then it was followed by many other studies, see e.g. Andersen (1979), Bergstrand (1985), Anderson and Wincoop (2003), Helpman et al. (2008) or Baier and Bergstrand (2009) to name a few. A concise review of gravity approach to international trade can be found e.g. in Anderson (2010).

Gravity models of trade are analogy to Newton's law of gravity:

$$F_g = \kappa \frac{m_1 \cdot m_2}{r^2}, \qquad (1)$$

Where F_g is a gravitation force, m_1 and m_2 are masses, r distance of both masses and κ (also denoted as G) is a gravitational constant.

The frictionless and aggregate gravity model of trade assumes that supply Y_i of a country i is attracted by a demand E_j of a country j, where d_{ij} denotes a distance of both countries, see Anderson (2010):

$$X_{ij} = \frac{Y_i E_J}{d_{ij}^{\ 2}} \qquad (2)$$

In alternative models gross domestic product or income per capita (along with a population) of both countries is used instead of supply and demand, see e.g. Anderson (1979). From a simple model (2) more sophisticated models with trade frictions (trade barriers) and disaggregated goods (frictions are different for different goods in reality) can be formulated, see Anderson (2010).

But these models have some drawbacks: firstly, *multiplying* a supply of one country by a demand of some other country in (2) makes little economic sense (and there is also a question how to measure demand in a country *i* for goods from a country *j*). Secondly, Newton's law of gravity describes the *force* resulting from interaction of two point-like masses at distance *r*, not a *flow*.

More suitable and natural physical analogy of a flow of goods (or money, labour, immigrants, etc.) is a flow of electric particles (electric current) represented in its simplest form by the Ohm's law:

$$I = \frac{V}{R} \tag{3}$$

In (3) I denotes an electric current (in ampers) through a conductor, V is a difference of electric potentials between both ends of a conductor (in volts) and R is a resistance of a conductor (in ohms).

As an analogy to Ohm's law the following law of (relative) exports will be considered:

$$E_{ij}(\%) = k_i \frac{GDP_j}{DIST_{ij}} \tag{4}$$

In (4) E_{ij} denotes share of an export (in %) from a country i to a country j, GDP_j is a gross domestic product of an importing country j (in billions of USD), $DIST_{ij}$ is a distance between countries i and j (given as an air distance of capital cities in kilometers), and k_i are (positive) constants.

It should be noted that if absolute values of exports (e.g. in billions of USD) were considered in (4) instead of relative exports, then only coefficients k_i would change, which in turn wouldn't influence properties of regression models based on (4).

Relation (4) states that the share of export rises when an importing country is closer and/or richer. Frictions of any kind (customs, borders, different languages, bureaucratic obstacles, etc.) are not considered here as well as structurality (different goods are traded under different conditions),

Because E_{ij} is given in (%), an export to all (n) trading partner countries must sum up to 100% for all countries:

$$\sum_{j=1}^{n} E_{ij} = 100\%, \forall i. \tag{5}$$

Also, from (4) it follows that two importing countries with equal GDP and distance from an exporting country i have the same share of export from this country. If an export was independent on a distance then export shares from a country i would be fully determined (proportional) by GDP of importing countries.

To account for possible trade frictions the model (4) can be extended to take the following form:

$$E_{ij} = k_i \frac{GDP_j}{DIST_{ij}(1 + F_{ij})}, \tag{6}$$

where F_{ij} denotes a friction in an export from a country i to a country j. In general $F_{ij} \neq F_{ji}$.

The aim of the article is to examine how the Export law (4) fits the export data for two selected Central European countries: Germany and the Czech Republic. These countries are suitably located in the middle of the continent surrounded by many trading partners in different distances unlike rather isolated countries such as Iceland, Ireland or Cyprus. Moreover, there are reliable data of their exporting partners.

2. The data and the method

For the empirical investigation of the flow model of export defined by relation (4) the following data were used:

- Exporting partners (shares in %) were obtained from Bridgat (2013), actualized in June 2013. Because the list of all exporting partners may be very long (including theoretically all countries of the World) and the data on partner countries with shares of only fractions of a percent are not sufficiently reliable and precise, the list was terminated when the sum of export shares of countries on the list exceeded 90%. The data on exporting partners for Germany and the Czech Republic is provided in Tables 1 and 2.
- Distances between a given country and its export partners (in km) were obtained from a distance calculator at Timeanddate (2013). The distance between two countries was defined as an air distance between their capital cities.
- GDP (PPP) in billion USD were retrieved from the International Monetary Fund (2012).

All the data for both countries are provided in Tables 1 and 2. It should be noted that export shares and GDP (PPP) change in time and are a subject of later revisions.

Table 1. The data for the Czech Republic as an exporter.

Exporter: CZECH REP.	EXPORT to (%)	DIST (km)	GDP (billion USD) PPP
Germany	32.390	280	3167
Slovakia	8.860	292	132
Poland	6.650	514	802
France	5.750	885	2252
United Kingdom	5.300	1034	2312
Austria	4.780	250	359
Russia	2.830	1664	2486
Italy	4.890	922	1813
Netherlands	3.940	707	710
Belgium	2.750	721	421
United States	1.760	6589	15653
Hungary	2.840	444	197
Spain	2.370	1773	1407
Switzerland	1.450	623	362
Sweden	1.820	1056	396
Romania	1.410	1076	274,1
Ukraine	0.970	1146	335

Source: IMF (2012), Bridgat (2013), Timeanddate (2013).

Table 2. The data for Germany as an exporter.

Exporter: GERMANY	EXPORT to (%)	DIST (km)	GDP (billion USD) PPP
France	9.9	879	2252
UK	6.91	932	2312
Netherlands	6.51	577	710
USA	7.96	6402	15653
Austria	5.4	523	359
Italy	6.59	1183	1813
China	3.69	7377	12261
Switzerland	4.15	752	362
Belgium	5.24	651	421
Poland	4.08	520	802
Spain	4.53	1870	1407
Russia	3.52	1616	2486
Czech Republic	2.85	280	287
Sweden	2.11	813	396
Hungary	1.82	691	197
Denmark	1.63	356	210
Turkey	1.62	2042	1125
Japan	1.36	8940	4575
Finland	0.96	1109	198
Korea	0.93	8150	1622
Slovakia	0.9	554	132
Brazil	0.9	9429	2230
Romania	0.87	1297	274,1
India	0.86	5793	4716
UAE	0.83	4641	271
Portugal	0.82	2315	245
Norway	0.82	840	278
Greece	0.79	1804	281
South Africa	0.75	8831	579
Mexico	0.75	9741	1758

Source: IMF (2012), Bridgat (2013), Timeanddate (2013).

For an examination of the theoretical model of international export given by relation (4) the following regression model is considered:

$$E_{ij} = k_i \cdot GDP_j^{\alpha} \cdot DIST_{ij}^{\beta} \tag{7}$$

Taking natural logarithms (all variables are positive) of both sides of (7) yields:

$$\ln E_{ij} = \ln k_i + \alpha \cdot \ln GDP_j + \beta \ln DIST_{ij} \tag{8}$$

The linear regression model (8) with corrected heteroscedasticity was tested with the use of the empirical data (for each country separately) from Tables 1 and 2. For the regression free statistical software Gretl was utilized.

3. Results

Results of linear regressions for the Czech Republic and Germany via the model (8) are shown in Tables 3 and 4. The model successfully models shares of export For both countries, as in the case of the Czech Republic both explanatory (independent) variables are highly significant ($p \le 10^{-5}$) and coefficient of determinacy is around 0.98. Also in the case of Germany both explanatory variables are highly significant ($p \le 10^{-3}$), but the coefficient of determinacy is smaller: 0.75. Generally, in both cases the model predicts exports shares successfully.
By the linear regression the following relationships were obtained:

- Czech Republic: $$E_j = e^{5.177} GDP_j^{0.652} DIST_j^{-1.241} \tag{9}$$
- Germany: $$E_j = e^{2.544} GDP_j^{0.600} DIST_j^{-0.784} \tag{10}$$

Values of coefficients *α, β* and *k* of the model (7) were found positive as expected for both countries. In both cases the coefficient *α* is close to 0.6, but *β* is higher in the absolute value than 1 in the case of the Czech Republic and smaller than 1 in the case of Germany. This result implies that a distance plays larger role in an export from the Czech Republic, or alternatively, that exporters from Germany are more capable of overcoming transportation distances (costs). Figures 1 and 2 demonstrate relationships (9) and (10) graphically.

Table 3. Linear regression characteristics: the Czech Republic.

CZECH REP.	coefficient	st. error	*t*-value	*p*-value	Signif.
const	5.17747	0.162231	31.9142	<0.00001	***
LOG__DIST_	-1.2412	0.046711	-26.5719	<0.00001	***
LOG__GDP_	0.652561	0.0425102	15.3507	<0.00001	***
determinacy coeff.		0.9869	Adj. determ. coeff.		0.9849
F (2,14)		525.9	*p*-value (F)		6.75e-14
Schwarz criterion		78.45	Aikake criterion		75.95

Source: own

Table 4. Linear regression characteristics: Germany.

GERMANY	coefficient	st. error	*t*-value	*p*-value	Signif.
const	2.54425	0.614688	4.1391	0.00031	***
LOG__DIST_	-0.784429	0.0882221	-8.8915	<0.00001	***
LOG__GDP_	0.600304	0.0790274	7.5962	<0.00001	***
determinacy coeff.		0.7677	Adj. determ. coeff.		0.7505
F (2,27)		44.63	p-value (*F*)		2.76e-09
Schwarz criterion		127.8	Aikake criterion		123.6

Source: own

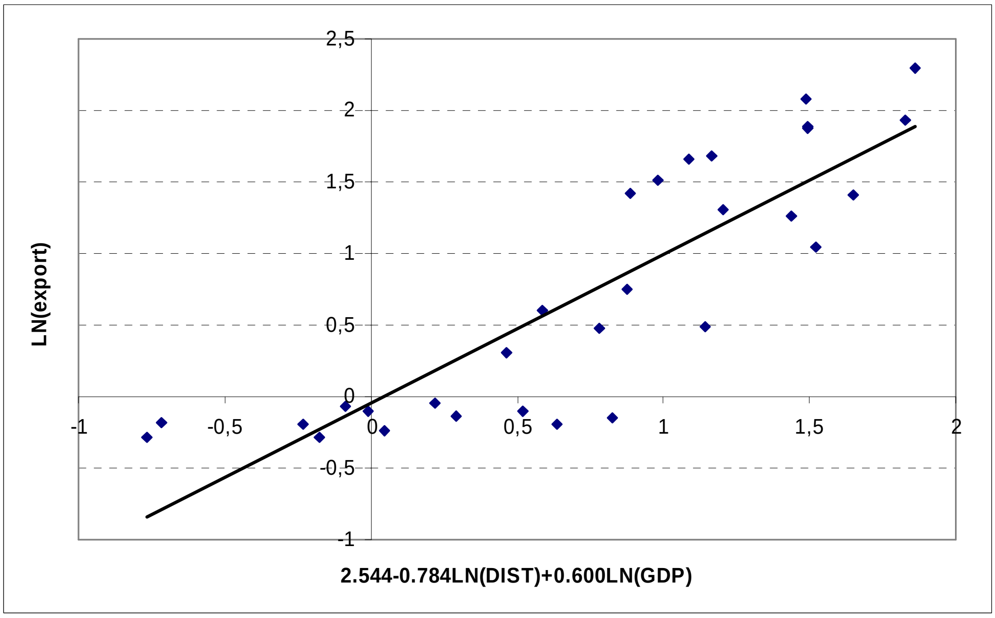

Figure 1. The relationship between logarithm of export and the combination of GDP and distance logarithms according to (9) for Germany, with the linear trend. Source: own.

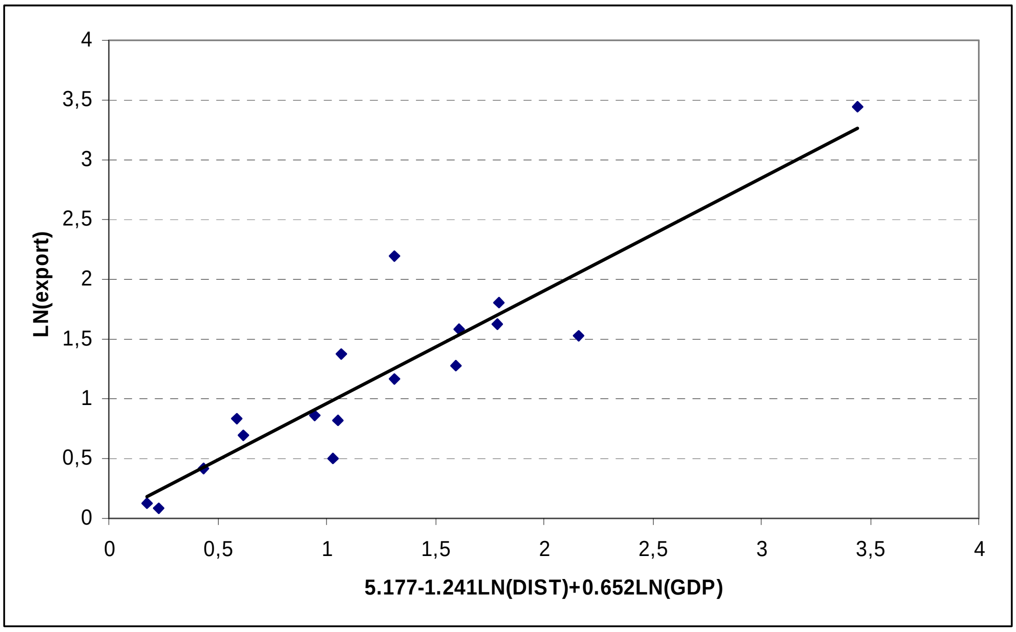

Figure 2. The relationship between logarithm of export and the combination of GDP and distance logarithms according to (9) for the Czech Rep., with the linear trend. Source: own.

4. Conclusions

The aim of this paper was to propose a new (flow) model of international export based on a gross domestic product and a distance of importing countries from a given exporting country. This is a different approach from standard gravity models used in the literature where also characteristics of exporting countries (income, GDP or population) are considered.

Empirical examination of export shares of two selected Central European countries (Germany and the Czech Republic) revealed that the model is very successful in fitting the data with coefficients of determinacy equal to 0.75 and 0.98 respectively.

Also, the model offers many directions to the subsequent research: it can be examined for other countries of the World (for example in Asia or Africa), for different types of economies (transition ones, open, free market, socialist, etc.) or for different years, it can be used for special goods (disaggregated models) or trade frictions, and at last but not for the least it can be compared with existing gravity models.

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