Extended Gravity Model of International Trade: An Empirical Application to Czech Trade Flows

Jana Šimáková
Silesian University in Opava
School of Business Administration in Karvina, Department of Finance
Univerzitní náměstí 1934/3
Karviná, 733 40
Czech Republic
e-mail: simakova@opf.slu.cz

Abstract
The aim of this paper is to investigate the effect of exchange rate volatility on bilateral trade flows between the Czech Republic and its major trading partners. For this purpose we employ extended trade gravity model approach. Trade volume between a pair of countries is modeled as an increasing function of their sizes (GDP) and a decreasing function of the distance between the two countries. Additional factors included in extended model are population, dummies for common border; membership in EU and proxy for exchange rate volatility. Generally is expected that increased exchange rate volatility increases the risk of exporters and reduces foreign trade. This paper explores relationship between trade and exchange rate volatility using quarterly data over the period 1997:1 – 2012:2. In order to obtain the objective result, we use the panel data regression with 17 trading partners. Based on a gravity model that controls for other factors likely to determine bilateral trade, the results suggest that nominal exchange rate volatility of Czech koruna has a significant negative effect on bilateral trade over the sample period.

Keywords: bilateral trade, exchange rate, gravity model, volatility
JEL codes: C51, F14, F31

1. Introduction

Usually, international trade tends to be a driver of the economy in countries neighboring with economies with open trade regimes, high presence of multinational companies and large volume of re-exports. Foreign trade is an integral part of the total development growth and national growth of an economy of the Czech Republic as well. The Czech Republic is a small open economy, which ratio of foreign trade to GDP is still growing during the time. This is evidenced by the increasing share of merchandise trade on its GDP. It was 83.2 % in 1997 in comparison to 151.9 % according to the latest World Bank data. International trade serves as a major channel of Czech economic integration in the European Union as a whole and it can be assumed that its higher intensity of foreign trade creates an environment for economically similar developments with related economies and causes vulnerability to any adverse changes in connected economies.

Generally is assumed, that higher exchange rate volatility leads to higher transaction costs for traders and is followed by decrease of foreign trade. Theoretical analyses of this relationship have been conducted by Hooper and Kohlhagen (1978), who argue, that if changes in exchange rates are unpredictable it means uncertainty about companies' profits and reduces the benefits of foreign trade. Even if hedging in the forward markets were possible, there are limitations and costs which are especially considerable for small firms. A reduction of the transaction costs associated with elimination of the exchange rate risk is argued to be important especially for countries that are characterized by the strong concentration of their trade with one large trading partner or a group of countries that share a common currency. This is the case for many Central and Eastern European countries for which Germany is the main trading partner, and more than 50 percent of their trade takes place with the members of the Eurozone (Cieślik et al., 2012).

From the Czech economy point of view is therefore important that the elimination of the exchange rate risk is supposed to stimulate exports of existing firms and encourage non-exporters that previously limited their operations to their domestic markets only to start exporting (Baldwin et al., 2005).

To analyze trade flows between countries have often been used a gravity models. The gravity model of international trade has become one of the standard tools for analyzing trade patterns and trade. In its usual modern expression, the gravity model brings hypotheses that the larger, the richer, the closer together two countries are, the more they trade between them.

Previously however, these models were applied to cross-section data, or to single country time-series data, which imposed severe explicit (or implicit) restrictions on the specification of the model. Recently gravity models have been generalized and adapted to a panel data setting, where several time-series of cross-section data sets were pooled. This approach not only increases the degree of freedom, it also enables the proper specification of source and target country effects and time (or business cycle) effects (Arvas, 2008).

Findings differ across the studies as well for aggregation reason. Rajan (2004) came to conclusion that there is no obvious negative relationship between aggregate exchange rate volatility and aggregate trade. When the research is turned to bilateral trade, we do find evidence that exchange rate volatility seems to more affect bilateral trade than the aggregate one. Evidence on the researched relationship between exchange rate volatility and trade flows is characterized as heterogenous as the results tend to be sensitive to the choices of sample period, model specification, proxies for exchange rate volatility and countries.

Therefore the aim of this paper is to investigate the effect of exchange rate volatility on bilateral trade flows between the Czech Republic and its major trading partners. Panel data used in this study covers period from 1997 to 2012 and 17 trading partners.

2. Gravity Equation of Foreign Trade

To estimate the impact of exchange rate volatility on foreign trade in this paper is used a gravity model, which is a simple empirical model for analyzing bilateral trade flows. Despite this approach was often criticized for insufficient theoretical foundations, this drawback has been eliminated in the recent years.

The original gravity equation is based on Newton´s gravity law equation:

$$F_{ij} = g\frac{m_i m_j}{d_{ij}^2} \qquad (1)$$

where F_{ij} is the value of gravity force, $m_{i(j)}$ is the weight of object *i (j)*, d_{ij} represents the distance between the objects and g is the gravity constant.

Based on this equation, the gravity model of trade analogous describes the force of gravity and explains the flow of trade between a pair of countries as being proportional to their economic “weight” (national income) and inversely proportional to the distance between them. The model has a lineage that goes back to Tinbergen (1962) and Pöyhönen (1963), who specified the gravity model equation as follows:

$$X_{ij} = \delta\frac{GDP_i^{\beta_1} GDP_j^{\beta_2}}{D_{ij}^{\theta}} \qquad (2)$$

where $\beta_{1(2)}$ and θ are the parameters of the modified equation, X_{ij} is the bilateral trade between countries (dependant variable), $GDP_{i(j)}$ represents income of respective trading partner *i(j)* (independent variable) D_{ij} is the distance between these two countries (independent variable) and δ is constant.

Trade theorists have found the model to be consistent with theories of trade based upon models of imperfect competition and with the Hecksher-Ohlin model. For example Carrere (2005) points out its microeconomic foundation. The gravity equation can be formally derived within an imperfectly competitive set up with increasing returns to scale and firm-level product differentiation as well as within a perfect competition set-up with product differentiation at the national level (Arricia, 1998). Countries with a larger economy tend to trade more in absolute terms as they have larger demand respectively supply. Higher distance depresses the bilateral trade as it represents higher costs for transportation, higher shipment time, and higher costs for searching trading opportunities. Distance can be used as proxy for cultural difference as well (Batra, 2004).

The basic gravity equation is frequently extended to incorporate other factors stimulating or reducing of bilateral trade flows. As an additional determinant of trade there is often used a population size of respective countries. Generally coefficient for country population is expected to be positive, since bigger market in the recipient country is expected to demand more goods. And population of the export country is expected to be able to supply more as the population grows in size. Recent models also include many dummy variables that can affect transaction costs. For example common border, language or memberships in custom union are supposed to decrease transaction costs and to promote trade (Arricia, 1998). Therefore inserting these variables in the model we obtain:

$$X_{ij} = e^{\delta} \frac{GDP_i^{\beta_1} GDP_j^{\beta_2} Pop_i^{\beta_3} Pop_j^{\beta_4}}{D_{ij}^{\theta}}^{\sum_l dum_l^{\gamma} + \varepsilon_{ij}} \qquad (3)$$

where $POP_{i(j)}$ stands for population of country *i(j)* participating in bilateral trade and *dum* represents dummy variables in addition to equation (3).

3. Extended Gravity Model with Exchange Rate Volatility

To analyze effects of exchange rate volatility on international trade flows of the Czech Republic, we employ an augmented gravity model equation. In this paper we express bilateral trade flows as a function:

$$X_{ij} = \alpha GDP_i^{\beta_1} GDP_j^{\beta_2} Pop_i^{\beta_3} Pop_j^{\beta_4} D_{ij}^{\beta_5} e^{\beta_6 V(ER)_{ij}} \prod_l dum_l^{\gamma_1} u_{ij} \qquad (4)$$

where additional factor ER_{ij} is the spot exchange rate than $V(ER)_{ij}$ is its volatility and α, β_k, γ_l are the unknown parameters of the model, *uij* is the error term. In order to add the exchange rate volatility into the equation, we follow Tichý (2007) and Baldwin et al. (2005) who pointed out that this relationship is not linear but convex and to avoid error due to rounding during data transformation, the volatility is used in exponent. Common border and membership in EU are incorporated in variable *dum*.

Transforming this function to log-linear form, we get an extended gravity model equation:

$$lnX_{ij} = \alpha + \beta_1 lnGDP_I + \beta_2 GDP_j + \beta_3 lnPop_i + \beta_4 lnPop_j + \beta_5 lnD_{ij} + \beta_6 lnV(ER)_{ij} + \sum_l \gamma_l dum_l + u_{ij} \qquad (5)$$

Logarithmic transformation helps to reduce skewness and heteroscedasticity and to stabilize variability. The stability of regressors is needed in empirical estimation.

3.1 Data Description

The models are estimated by using quarterly data over the period 1997:1 – 2012:2. The dependent variable in the model is a volume of bilateral trade between Czech Republic and its trade partner, which is given as a sum of bilateral export and import flows of respective country. Trade flows are obtained from the OECD statistics of international trade. The data are in current prices and denominated in the US dollars. The countries selection is based on the share of total international trade turnover and their list can be seen in table 1.

Table 1: Main Trading Partners of the Czech Republic

Austria	Hungary	Portugal
Belgium	Italy	Spain
Denmark	Luxembourg	Sweden
Finland	Netherland	Switzerland
France	Norway	United Kingdom
Germany	Poland	

Source: author´s calculation

GDP for every country is also obtained from OECD statistics of national accounts, calculated by expenditure approach in millions of US dollars in current prices. Time series for population is acquired from Eurostat. Distance and common border between the Czech Republic and its trading partner are used based on GeoDist database made by Mayer and Zignago (2012). They made available the exhaustive set of gravity variables, in particular bilateral distances measured using city-level data. Exchange rates are obtained from OECD statistics of international trade and are the only variables on monthly frequency. The basic statistical description of data is stated in table 2.

Table 2: Data Description

Variable	Observations	Mean	Minimum	Maximum
lnX_{ij}	1054	19.05880	15.10758	22.77945
$lnGDP_i$	1054	12.24881	12.02958	12.45201
$lnGDP_j$	1054	12.89104	9.938832	14.86342
$lnPOP_i$	1054	9.242356	9.229976	9.264052
$lnPOP_j$	1054	9.515748	11.32105	6.035242
lnD_{ij}	1054	6.676721	5.531205	7.716592
$lnV(ER)_{ij}$	1054	14.60863	2.368040	19.59422
Common border (*CB*)	= 1, if trading partner shares a common border with the Czech Republic; = 0 if not			
EU member (*EU*)	= 1, if trading partner is a member of EU; = 0 if not			

Source: author´s calculation

3.2 Measuring of Exchange Rate Volatility

To measure the exchange rate volatility in this paper is used standard deviation of the first difference, based on monthly average nominal exchange rates of the period of 1997:1 to 2012:6. We employ following formula:

$$V(ER)_{ij} = \sqrt{\frac{\sum_{m=1}^{n}(ER_{ij,m}-ER_{ij,t})^2}{n}} \quad (6)$$

In this paper is used nominal exchange rate, as nominal and real exchange rates tend to move closely together and the choice is not likely to the econometric results. As literature review made by Auboin and Rutha (2012) states, the probability that the variability of nominal exchange rates did not translate into that of the real exchange rate would be small, occurring only during exceptionally high periods of domestic inflation. In empirical studies, both variables are generally tested. In addition, using nominal exchange rate avoids bias from changes in price levels via spurious correlation.

3.3 Estimation of Gravity Model

As Arvas (2008) states, standard gravity models usually employ cross-section data to estimate trade patterns in a given year, or averaged data. We employ panel data regression to avoid the risk of choosing an unrepresentative year and to monitor unobservable individual effects between trading partner. This can provide additional insights to trading relationships. In addition using of panel data for estimation brings mostly significant relationship between international trade and exchange rate volatility.

Before estimating ordinary least squares (OLS) based method on panel data, it is needed to determine data set effects as random or fixed. The fixed effects are when the heterogeneity in the model is unobservable, but correlated with any variable included in model. Per contra, the heterogeneity in random effects is also unobservable, but it is not correlated with any other variable. In this case we follow Tichý (2007) again. The Breusch-Pagan Langrage multiplier test is used and the test criteria are calculated from equation:

$$LM = \frac{nT}{2(T-1)}\left[\frac{\sum_{i'1}^{n}\left(\sum_{t'1}^{T} e_n\right)^2}{\sum_{i=1}^{n}\sum_{t=1}^{T} e_{it}^2} - 1\right]^2 \quad (7)$$

where T is the length of time series, n is the number of unit in cross-section dimension and e_{it} is a residuum.

4. Empirical Results

The estimation of the Breusch-Pagan Langrage multiplier test revealed random effects. Thus the extended gravity model is estimated by least squares method for panel data. The dependent variable in the model is total trade turnover between the Czech Republic and its trading partners. We have included 17 cross-sections and 62 periods. Total panel observations are 1054. The value of adjusted R-squared in this model is 93.99 %. The results of this estimation can be seen in table 3.

Table 3: Regression Results

Variable	Coefficient	Std. Error	t-Statistic	Prob.
$lnPOP_i$	-1.889780	1.349102	-1.400769	0.1616
$lnPOP_j$	0.236954	0.043783	5.411976	0.0000
$lnGDP_i$	3.925579	0.100008	39.25268	0.0000
$lnGDP_j$	0.708254	0.048399	14.63354	0.0000
lnD_{ij}	-1.132039	0.031779	-35.62192	0.0000
$lnV(ER)$	-0.030785	0.005261	-5.850962	0.0000
CB	0.419417	0.043530	9.635207	0.0000
EU	0.031121	0.039396	0.789959	0.4297
C	-15.03722	11.70727	-1.284434	0.1993

Source: author´s calculation

Except parameter of dummy variable of membership in the European Union and variable of the Czech population, all estimated parameters are statistically significant. We can observe expected positive impact of foreign population, Czech and foreign GDP. Per contra, there is confirmed supposed indirect relationship between trade volume distance and volatility of exchange rates. As can be seen in results, the effect of exchange rate volatility is very small.

5. Conclusion

The aim of the paper was to investigate the impact of volatility of Czech koruna on bilateral trade flows between the Czech Republic and its major trading partners. For this purpose we employed extended trade gravity model approach. We included 17 trading partners into the panel data analysis and the results suggest that the nominal exchange rate volatility of Czech koruna has a significant negative, but weak effect on bilateral trade over the sample period. Therefore, the results indicate that an active exchange rate policy aimed to influence exchange rate development is not supposed to promote any notable improvement of Czech international trade.

Acknowledgement

The publication of this paper was supported by the Student Grant System of Silesian University (project SGS/7/2013).

References

ABEYSINGHE, T., YEAK, T.J. (1998). Exchange rate appreciation and export competitiveness. The case of Singapore. *Applied Economics,* vol. 30, no. 1, pp. 51-55.

ARRICIA, G.D. (1998). *Exchange rate Fluctuations and Trade Flows: Evidence from the European Union.* IMF Working Paper WP/98/107. Washington, D.C.: International Monetary Fund.

ARVAS, A.M. (2008). Does Real Exchange rate Matter for Emerging Markets´ International Trade? A Gravity Model Approach for Turkey. In *Proceedings of First International Conference on Management and Economics.* Tirana, Albania: Epoka University Research and Application Center, pp. 77-96.

AUBOIN, M., RUTA, M. (2012). *The Relationship between Exchange Rates and International Trade: A Literature Review.* CESifo Working Paper Series 3868. Munich: CESifo Group Munich.

BALDWIN, R., SKUDELNY, F., TAGLIONI, D. (2005). *Trade Effects of the Euro, Evidence from Sectoral Data.* ECB Working Paper Series 446. Frankfurt am Main: Europen Central Bank.

BATRA, A. (2006*).* India's Global Trade Potential: The Gravity Model Approach. *Global Economic Review: Perspectives on East Asian Economies and Industries,* vol. 35, no. 3, pp. 327-361.

CARRERE, C. (2005). *Regional Agreements and Welfare in the South:When Scale Economies in Transport Matter*. CERDI Working Papers 200513. Clermont-Ferrand: CERDI.

CIEŚLIK, A., MICHAŁEK, J.J., MYCIELSKI, J. (2012). *Consequences of the euro adoption by Central and Eastern European (CEE) countries for their trade flows*. NBP Working Paper No. 118. Warsaw: National Bank of Poland.

DE GRAUWE, P. (1988). *Exchange Rate Variability and the Slowdown in the Growth of International Trade.* IMF Staff Papers 35. Washington, D.C.: International Monetary Fund.

HOOPER, P., KOHLHAGEN, S.W. (1978). The effect of exchange rate uncertainty on the prices and volume of international trade. *Journal of International Economics*, vol. 8, no. 4, pp. 483-511.

MAYER, T., ZIGNAGO, S. (2012). *Notes on CEPII's distance measure*. MPRA Paper 36347. Paris: Banque de France.

OZTURK, I. (2006) Exchange Rate Volatility and Trade: A Literature Survey. *International Journal of Applied Econo-metrics and Quantitative Studies,* vol. 3, no. 1, pp. 85-102.

PÖYHÖNEN, P. (1963). A Tentative Model for the Volume of Trade Between Countries. *Weltwirtschaftliches Archiv*, vol. 90, pp. 93-100.

RAJAN, R. (2004): *Exchange Rate Volatility and Trade Flows - Some New Evidences.* IMF Occasional Paper 235, Washington, D.C.: International Monetary Fund.

TAGLIONI, D. (2002). Exchange Rate Volatility as a Barrier to Trade: New Methodologies and Recent Evidences. *Economie Internationale,* vol. 1, no. 2, pp. 227-259.

TICHÝ, F. (2007). Impact of Accesion to EMU on International Trade – Case of the Czech Republic. *Prague Economic Papers,* vol. 4, pp. 336-346.

TINBERGEN, J. (1962). *Shaping the World Economy: Suggestions for an International Economic Policy*. New York: Twentieth Century Fund.