AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
<http://ageconsearch.umn.edu>
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

DISCUSSION PAPER

**Leibniz Institute of Agricultural Development
in Transition Economies**

Gravity Model Estimation: Fixed Effects vs. Random Intercept Poisson Pseudo Maximum Likelihood

**Sören Prehn, Bernhard Brümmer,
Thomas Glauben**

**DISCUSSION PAPER No. 148
2014**

Leibniz Institute of Agricultural Development
in Transition Economies

Theodor-Lieser-Straße 2, 06120 Halle (Saale), Germany
Phone: +49-345-2928-110
Fax: +49-345-2928-199
E-mail: iamo@iamo.de
Internet: <http://www.iamo.de>

Dr. Sören Prehn, Research Associate, Leibniz Institute of Agricultural Development in Transition Economies (IAMO).

Prof. Dr. Bernhard Brümmer, Holder of the Chair of Agricultural Market Analysis, Georg-August-University Göttingen.

Prof. Dr. Thomas Glauben, Director, Leibniz Institute of Agricultural Development in Transition Economies (IAMO) and Professor, Universität Halle-Wittenberg.

Address:	Leibniz Institute of Agricultural Development in Transition Economies (IAMO) Theodor-Lieser-Straße 2 06120 Halle (Saale) Germany
Phone:	++49-345-2928-248
Fax:	++49-345-2928-299
E-mail:	prehn@iamo.de
Internet:	http://www.iamo.de

Discussion Papers are interim reports on work of the Leibniz Institute of Agricultural Development in Transition Economies and have received only limited reviews. Views or opinions expressed in them do not necessarily represent those of IAMO. Comments are welcome and should be addressed directly to the author(s).

The series *Discussion Papers* is edited by:

Prof. Dr. Alfons Balmann (IAMO)
Dr. Stephan Brosig (IAMO)
Prof. Dr. Thomas Glauben (IAMO)
Dr. Daniel Müller (IAMO)
Prof. Dr. Heinrich Hockmann (IAMO)
Prof. Dr. Martin Petrick (IAMO)

ISSN 1438-2172

ABSTRACT

Since the work of FEENSTRA (2002), the standard ANDERSON & VAN WINCOOP (2003) Gravity Model has been estimated using a fixed effects approach. However, a fixed effects approach has a major drawback: it does not allow for the estimation of exporter- and importer-invariant variables. Thus, economically relevant variables such as exporter and importer gross domestic product are disregarded. Here, we propose a random intercept model to address this gap. This approach not only provides identical estimates to a fixed effects approach, but also allows for the estimation of exporter- and importer-invariant variables.

JEL: F1, C3

Keywords: Gravity Model Estimation, Poisson Pseudo Maximum Likelihood, Fixed Effects Model, Random Intercept Model.

ZUSAMMENFASSUNG

GRAVITY MODELL SCHÄTZUNG: FIXED EFFEKTS VS. RANDOM INTERCEPT POISSON
PSEUDO MAXIMUM LIKELIHOOD

Seit FEENSTRA (2002) wird das Standard ANDERSON & VAN WINCOOP (2003) Gravity Modell mittels Fixed-Effects-Ansatzes geschätzt. Der Fixed-Effects-Ansatz hat allerdings den entscheidenden Nachteil, dass er nicht die Schätzung von Exporteur- und Importeur-invarianten Variablen erlaubt. Folglich lassen sich ökonomisch relevante Variablen wie Exporteur- und Importeur-Bruttosozialprodukt nicht berücksichtigen. Wir empfehlen ein Random-Intercept-Modell anstatt. Dieser Ansatz liefert nicht nur die identischen Schätzer wie ein Fixed-Effects-Modell, sondern erlaubt auch die Schätzung von Exporteur- und Importeur-invarianten Variablen.

JEL: F1, C3

Schlüsselwörter: Gravity Modell, Poisson Pseudo Maximum Likelihood, Fixed Effects Modell, Random Intercept Modell.

Abstract. Since FEENSTRA (2002), the standard ANDERSON & VAN WINCOOP (2003) Gravity Model is estimated by a fixed effects approach. Still, a fixed effects approach has a major drawback: it does not allow for the estimation of exporter- and importer-invariant variables. Thus, economically relevant variables such as exporter and importer gross domestic product are disregarded. Here, we propose a random intercept model instead. This approach not only gives identical estimates like a fixed effects approach but also allows for the estimation of exporter- and importer-invariant variables.

Keywords: Gravity Model Estimation, Poisson Pseudo Maximum Likelihood, Fixed Effects Model, Random Intercept Model

Similar to the ongoing discussion about the appropriate theoretical specification of gravity models (ANDERSON, 1979), debate continues about the consistent estimation of gravity models (SANTOS SILVA & TENREYRO, 2006). The ANDERSON & VAN WINCOOP (2003) (AvW) Model is now state-of-the-art; these authors show that one must account for outward and inward multilateral resistance, otherwise estimation results are biased. Not accounting for outward and inward multilateral resistance leads to an omitted variable bias. The AvW Model is defined as follows:

$$X_{ij} = \left(\frac{Y_i Y_j}{Y^w} \right) \left(\frac{\tau_{ij}}{\Pi_i P_j} \right)^{1-\sigma}$$

with

$$\begin{aligned} \Pi_i^{1-\sigma} &= \sum_j \left(\frac{\tau_{ij}}{P_j} \right)^{1-\sigma} \frac{Y_j}{Y^w} \\ P_j^{1-\sigma} &= \sum_i \left(\frac{\tau_{ij}}{\Pi_i} \right)^{1-\sigma} \frac{Y_i}{Y^w}, \end{aligned}$$

where X_{ij} is the export value from exporter i to importer j , τ_{ij} are bilateral trade costs between i and j , and Π_i and P_j are outward and inward multilateral resistance, respectively. The variables Y_i , Y_j , and Y^w are i 's, j 's, and world gross domestic product, while σ indicates the elasticity of substitution.

Although ANDERSON & VAN WINCOOP recommend estimating their model using a nonlinear programming approach, it is now standard practice to estimate the AvW Model using a fixed effects approach. In Feenstra's seminal article 'Border Effects and the Gravity Equation: Consistent Methods for Estimation' (SCOTTISH JOURNAL OF POLITICAL ECONOMY, 49, 5: pp. 491-06), he shows that one does not commit an error when estimating the AvW Model using a fixed effects approach. Rather, the coefficients of source and destination fixed effects are consistent measures for outward and inward multilateral resistance.

In practice, the AvW Model is usually estimated by a fixed-effects Poisson Pseudo Maximum Likelihood (PPML) approach (SANTOS SILVA & TENREYRO, 2006). The PPML has several advantages compared to other estimators; it deals appropriately with heteroscedasticity, model misspecification, and excess zeros. The fixed effects approach, however, has one major drawback: it does not allow for the estimation of exporter- and importer-invariant variables, i.e., variables such as exporter and importer gross domestic product (GDP) cannot be estimated when a fixed effects approach is applied. The lack of within-group variation in the former variables makes it impossible to identify them. This is a problem because variables such as GDP and so on are economically interesting in trade analysis. It would therefore be important to understand how they impact trade.

One can argue in favor of a random effects model. However, a random effects model has other shortcomings. Commonly, the independence assumption of residuals and covariates is not fulfilled. An alternative is a random intercept model, which combines the advantages of a fixed effects model and that of a random effects model (RABE-HESKETH & SKRONDAL, 2012). A random intercept model uses both within-group variation and between-group variation for estimating. Hence, a random intercept model not only yields estimates that are identical to a fixed effects model, but also allows for the estimation of exporter- and importer-invariant variables.¹ The latter particularly increases the explanatory power of the standard AvW Model.

Implementing PPML is as simple to implement as a random intercept PPML. The corresponding random intercept PPML model is given as follows:

$$X_{ij} = \exp(\beta_0 + \beta_1(\tau_{ij} - \bar{\tau}_i - \bar{\tau}_j + \bar{\tau}_{..}) + \beta_2 Y_i + \beta_3 Y_j + \zeta_{0i} + \zeta_{0j}) + e_{ij},$$

where β_0 indicates a constant. The Random exporter intercept is $\zeta_{0i} \sim N(0, \sigma_{\zeta_{0i}}^2)$, the random importer intercept is $\zeta_{0j} \sim N(0, \sigma_{\zeta_{0j}}^2)$, and the error term is $e_{ij} \sim N(0, \sigma_e^2)$. As with a fixed effects model, some data transformations are required in advance. For the fixed effects portion, variables associated with bilateral trade costs have to be transformed as follows: $\tau_{ij}^{\text{within}} = \tau_{ij} - \bar{\tau}_i - \bar{\tau}_j + \bar{\tau}_{..}$, where bars and dots indicate the corresponding means over importer and/or exporter, respectively.² As random intercept models belong to the broader class of mixed effects models, standard estimation routines can be used.³ In R, the corresponding function is `glmer` included in the R package `lme4` (BOLKER, 2014). The R command is

$$\text{glmer}(X_{ij} \sim \tau_{ij}^{\text{within}} + Y_i + Y_j + (1|\text{exp}_{id}) + (1|\text{imp}_{id}), \text{family} = \text{poisson}()),$$

where `expid` and `impid` indicate exporter and importer identification. Estimates can still be interpreted as before, i.e., variables in logs as elasticities and variables in levels as semi-elasticities.

For illustration, we revisit the famous ANDERSON & VAN WINCOOP example where border effects within and between United States and Canada are analyzed. Feenstra uses the same dataset as a benchmark.⁴

¹ If one only focuses on positive trade flows, the approximation approach of trade-cost effects by BAIER & BERGSTRAND (2009) is alternative. This approach, however, is not applicable to zero trade flows.

² For a panel model, a time-varying random intercept model is required (BALDWIN & TAGLIONI, 2007). The corresponding data transformation is $\tau_{ijt}^{\text{within,time-varying}} = \tau_{ijt} - \bar{\tau}_{i,t} - \bar{\tau}_{j,t} + \bar{\tau}_{..t}$.

³ A mixed effects approach is also recommended by PROENCA et al. (2012). The authors, however, favor a semi-mixed effects approach. Here, the assumption of identical preferences is skipped.

⁴ For details, see FEENSTRA (2002) and ANDERSON & VAN WINCOOP (2003).

Table 1: Comparison Gravity Estimators

	Without Zeros		With Zeros	
	Fixed Effects Model	Random Intercept Model	Fixed Effects PPML	Random Intercept PPML
	(1)	(2)	(3)	(4)
Year of data	1993	1993	1993	1993
Independent variables				
$\ln Y_i$	1	1.13*** (0.05)	1	0.73*** (0.11)
$\ln Y_j$	1	0.97*** (0.03)	1	0.91*** (0.03)
$\ln d_{ij}$	-1.25*** (0.04)	-1.25*** (0.04)	-1.01*** (0.04)	-1.01*** (0.00)
Indicator border	-1.55*** (0.07)	-1.55*** (0.06)	-1.24*** (0.10)	-1.24*** (0.00)
Observations	1511	1511	1560	1560

Source: Own calculations.

Note: Standard errors appear in parentheses. Fixed effects and random intercepts are not presented.

Table 1 contrasts Feenstra's fixed effects model (column 1) with a random intercept model (column 2), a fixed effects PPML approach (column 3), and a random intercept PPML approach (column 4). As argued above, for the fixed effects portion, one obtains identical estimates for distance and common border for log-linear models (column 1-2) and for multiplicative models (column 3-4). Further, for the random intercept models (column 2 and 4) one also obtains estimates for exporter and importer gross domestic product. Hence, applying random intercept models allows the researcher to gain additional insight into the drivers of bilateral trade.

The analysis, however, is not only restricted to exporter and importer gross domestic product. Rather, other exporter- and importer-invariant variables such as tariffs, infrastructure and so on can also be analyzed. This makes random intercept models a very valuable tool for analyzing policy-relevant variables in a standard AvW Model setting.

CONCLUSIONS

It is common practice to estimate gravity models using a fixed effects approach. However, such an approach has a major drawback: it does not allow for the estimation of exporter- and importer-invariant variables. The trade impact of economically relevant variables is disregarded. Random intercept models are a solution because they not only use within-group variation but also between group variation for estimation. One therefore obtains estimates for both variant and exporter- and importer-invariant variables.

In future, the standard AvW Model should be estimated by random intercept models. This would significantly increase the scope of questions that can be analyzed in a standard AvW Model setting. Besides bilateral trade costs, the trade impact of policy relevant variables such as tariffs, infrastructure and so on can be analyzed. Gravity models thus become more favorable for policy analyses.

REFERENCES

- ANDERSON, J. E. (1979): A Theoretical Foundation for the Gravity Equation. *American Economic Review*, 69, 1: pp. 106-16.
- ANDERSON, J. E., VAN WINCOOP, E. (2003): Gravity with Gravitas: A Solution to the Border Puzzle. *American Economic Review*, 93, 1: pp. 170-92.
- BAIER, S. L., BERGSTRAND, J. H. (2009): Bonus vetus ols: A simple method for approximating international trade-cost effects using the gravity equation. *Journal of International Economics*, 77, 1: pp. 77-85.
- BALDWIN, R., TAGLIONI, D. (2007): Trade Effects of the Euro: A Comparison of Estimators. *Journal of Economic Integration*, 22, 4: pp. 780-818.
- BOLKER, B. (2014): Package 'lme4'. <http://cran.r-project.org/web/packages/lme4/lme4.pdf>.
- FEENSTRA, R. C. (2002): Border Effects and the Gravity Equation: Consistent Methods for Estimation. *Scottish Journal of Political Economy*, 49, 5: pp. 491-506.
- PROENCA, I., SPERLICH, S., SAVASCI, D. (2012): "From the Log of Gravity toward a semi-mixed effects Gravity Model for Bilateral Trade". Paper presented at European Economic Association & Econometric Society, 2012 Parallel Meeting, 27-31 August 2012, Malaga/Spain.
- RABE-HESKETH, S., SKRONDAL, A. (2012): Multilevel and Longitudinal Modeling using STATA, Volume II: Categorical Responses, Counts, and Survival. STATA Press, Texas, US.
- SANTOS SILVA, J. M. C., TENREYRO, S. (2006): The Log of Gravity. *The Review of Economics and Statistics*, 88, 4: pp. 641-658.

**DISCUSSION PAPERS
DES LEIBNIZ-INSTITUTS FÜR AGRARENTWICKLUNG
IN TRANSFORMATIONSÖKONOMIEN (IAMO)**

**DISCUSSION PAPERS
OF THE LEIBNIZ-INSTITUTE OF AGRICULTURAL DEVELOPMENT
IN TRANSITION ECONOMIES (IAMO)**

- No. 129 MÖLLER, L., HENRIETTE HENTER, S., KELLERMANN, K., RÖDER, N., SAHRBACHER, C., ZIRNBAUER, M. (2010):
Impact of the Introduction of Decoupled Payments on Functioning of the German Land Market. Country Report of the EU Tender: "Study on the Functioning of Land Markets in those EU Member States Influenced by Measures Applied under the Common Agricultural Policy"
- No. 130 WOLZ, A., BUCHENRIEDEDER, G., MARKUS, R. (2010):
Renewable energy and its impact on agricultural and rural development: Findings of a comparative study in Central, Eastern and Southern Europe
- No. 131 KOESTER, U., PETRICK, M. (2010)
Embedded institutions and the persistence of large farms in Russia
- No. 132 PETRICK, M. (2010)
Zur institutionellen Steuerbarkeit von produktivem Unternehmertum im Transformationsprozess Russlands
- No. 133 MARQUARDT, D. (2010):
Rural networks in the funding period 2007-2013: A critical review of the EU policy instrument
- No. 134 FRITZSCH, J., MÖLLERS, J., BUCHENRIEDEDER, G. (2011):
DELIVERABLE 7.5 "Employment diversification of farm households and structural change in the rural economy of the New Member States"
- No. 135 GRAUBNER, M. (2011):
The Spatial Agent-based Competition Model (SpAbCoM)
- No. 136 WOLZ, A. (2011):
Institutional change of the agricultural administration and rural associations in East Germany before and after unification
- No. 137 PETRICK, M., WANDEL, J., KARSTEN, K. (2011):
Farm restructuring and agricultural recovery in Kazakhstan's grain region: An update

- No. 138 PREHN, S., GLAUBEN, T., PIES, I., WILL, M. G., LOY, J.-P. (2013):
Betreiben Indexfonds Agrarspekulation? Erläuterungen zum Geschäftsmodell und zum weiteren Forschungsbedarf
- No. 139 WOLZ, A. (2013):
The organisation of agricultural production in East Germany since World War II: Historical roots and present situation
- No. 140 MÖLLERS, J., MEYER, W., XHEMA, S., BUCHENRIEDER, G. (2013):
A socio-economic picture of kosovar migrants and their origin farm households
- No. 141 PETRICK, M. (2013):
Competition for land and labour among individual farms and agricultural enterprises: Evidence from Kazakhstan's grain region
- No. 142 PREHN, S., GLAUBEN, T., LOY, J.-P., PIES, I., WILL, M. G. (2013):
Der Einfluss von Long-only-Indexfonds auf die Preisfindung und das Marktergebnis an landwirtschaftlichen Warenterminmärkten
- No. 143 WEIß, W., WOLZ, A., HERZFELD, T., FRITZSCH, J. (2013):
Sozialökonomische Effekte des demographischen Wandels in ländlichen Räumen Sachsen-Anhalts
- No. 144 BIRHALA, B., MÖLLERS, J. (2014):
Community supported agriculture in Romania. Is it driven by economy or solidarity?
- No. 145 PETRICK, M., OSHAKBAEV, D., WANDEL, J. (2014):
Kazakhstan's wheat, beef and dairy sectors: An assessment of their development constraints and recent policy responses
- No. 146 POMFRET, R. (2014):
Trade costs and agricultural trade in Central Asia
- No. 147 PREHN, S., GLAUBEN, T., LOY, J.-P., PIES, I., WILL, M. G. (2014):
The impact of long-only index funds on price discovery and market performance in agricultural futures markets
- No. 147 PREHN, S., BRÜMMER, B., GLAUBEN, T. (2014):
Gravity Model Estimation: Fixed Effects vs. Random Intercept Poisson Pseudo Maximum Likelihood

Die Discussion Papers sind erhältlich beim Leibniz-Institut für Agrarentwicklung in Transformationsökonomien (IAMO) oder im Internet unter <http://www.iamo.de>.

The Discussion Papers can be ordered from the Leibniz Institute of Agricultural Development in Transition Economies (IAMO). Use our download facility at <http://www.iamo.de>.