



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.*

*Structural Gravity Estimation & Agriculture**

Sören Prehn^{††}, Bernhard Brümmer[§], Thomas Glauben[‡]

[‡]*Department of Agricultural Markets, Marketing and World Agricultural Trade*

Leibniz Institute of Agricultural Development in Central and Eastern Europe

[§]*Department of Agriculture Economics and Rural Development*

Georg August Universität Göttingen

Abstract

Recently, discussion about the appropriate estimation of gravity trade models has started in agriculture. Here, we are going to review recent developments in the literature. It appears that fixed effects Poisson Pseudo Maximum Likelihood is not only the only consistent estimator [[Santos Silva and Tenreyro, 2006](#)] but also it already allows for a structural fit [[Fally, 2012](#)]. Fixed effects in conjunction with the adding-up property of Poisson Pseudo Maximum Likelihood - which has been so far neglected - can be harnessed to directly deduce multilateral resistance indexes (i.e. general equilibrium effects) from reduced-form estimation. This innovation made by [Fally](#) will ease comparative statics and incidence analysis, making Poisson Pseudo Maximum Likelihood even more preferable in practice.

Keywords: Gravity Estimation, Poisson Pseudo Maximum Likelihood, Adding-up, Structural Fit

* Prehn gratefully acknowledges financial support from the Georg Christoph Lichtenberg Stiftung of the State Lower Saxony.

[†] Corresponding author. Leibniz-Institut für Agrarentwicklung in Mittel- und Osteuropa, Abteilung Agrarmärkte, Agrarvermarktung und Weltagrarhandel, Theodor-Lieser-Str. 2, 06120 Halle (Saale), Germany. Phone: +49 (0) 345 2928 248.

Email address: prehn@iamo.de (Sören Prehn)

1 Introduction

Appropriate estimation techniques of gravity trade models have been discussed recently in agricultural economics.¹² Agriculture in particular is a special case as one focuses on a micro sector and thus on disaggregate trade flows. Here, one has to deal with excess zeros and heteroskedasticity. Different estimators have been proposed (i.e. zero-inflated count data models) [Burger et al., 2009], however all of them have their disadvantages, such as suffering from in particular model misspecification and scale dependence [Prehn and Brümmer, 2011]. If one does not explicitly focus on the extensive and intensive margin of trade [Helpman et al., 2008], fixed effects Poisson Pseudo Maximum Likelihood (PPML) [Santos Silva and Tenreyro, 2006] seems to be the only reliable estimator. As shown, PPML is consistent against model misspecification and heteroskedasticity [Staub and Winkelmann, 2012]; recent research even shows that PPML can consistently handle excess zeros [Santos Silva and Tenreyro, 2011].

However, PPML has an additional advantage that has been so far neglected in the literature. PPML already allows for a structural fit of the gravity trade model. As Fally [2012] shows estimated fixed effects are consistent with the definitions of multilateral resistance indexes (i.e. general equilibrium effects) and the equilibrium constraints that they have to satisfy. Given the adding-up property of PPML (i.e. fitted output/expenditure equals observed output/expenditure), fixed effects can already be harnessed to directly deduce multilateral resistance indexes from reduced-form estimation. Fally’s approach is insofar promising as it combines the advantages of a reduced-form estimation with that of a structural estimation, i.e. one can stay with the very handy PPML for estimation and for the construction of multilateral resistance indexes just observed output and expenditure, and estimated fixed effects are required. Fally’s approach should significantly ease comparative statics and incidence analysis; conducting trade policy analyses in a gravity trade model context should become much easier.

In the following, we are going to review the recent literature on gravity trade model estimation with a special emphasis on agriculture. However, the standard Anderson and van Wincoop Model [2003] will be introduced before the review to establish a common basis for discussion. Afterwards, different estimators are compared before we moving on to the estimation framework. Finally, we conclude.

2 A *Structural* Gravity Trade Model

The Anderson and van Wincoop Model is the first *structural* gravity trade model that explicitly accounts for general equilibrium effects, i.e. not only absolute changes in bilat-

¹Here and in the following, the notation gravity trade model always refers to the standard Anderson and van Wincoop Model [2003].

²See e.g. Prehn and Brümmer [2012], Kotchoni and Larue [2012], Haq et al. [2012], Xiong and Sixia [2012] and Philippidis et al. [2011].

eral trade costs are considered but also relative changes in relation to changes in average bilateral trade costs. Bilateral trade costs are compared to both average bilateral trade costs of the respective importer and those of the respective exporter. Following [Anderson and van Wincoop](#), these average bilateral trade costs are also referred to as inward and outward multilateral resistance index, respectively.

The *structural* model is given in equation [1] – [3].

$$[1] \quad X_{ijk} = \frac{Y_{ik}}{\Pi_{ik}^{-\theta_k}} \times D_{ijk}^{-\theta_k} \times \frac{E_{jk}}{P_{jk}^{-\theta_k}}$$

$$[2] \quad P_{jk}^{-\theta_k} = \sum_i \frac{Y_{ik} D_{ijk}^{-\theta_k}}{\Pi_{ik}^{-\theta_k}}$$

$$[3] \quad \Pi_{ik}^{-\theta_k} = \sum_j \frac{E_{jk} D_{ijk}^{-\theta_k}}{P_{jk}^{-\theta_k}}$$

where, X_{ijk} denotes the export value of country i to country j in sector k , Y_{ik} i 's total sectoral output, and E_{jk} j 's total sectoral expenditure. In addition, D_{ijk} captures sector-specific bilateral trade costs from i to j , and θ_k is the corresponding sectoral trade flow elasticity. Π_{ik} is a sectoral measure for i 's outward multilateral resistance and P_{jk} for j 's inward multilateral resistance.

It is common practice first to estimate the reduced-form model [1] by means of a fixed effects approach [[Feenstra, 2004](#)],³ where the corresponding econometric model is given as

$$[4] \quad X_{ijk} = \exp [\alpha_0 + e_{ik} - \theta_k D_{ijk} + m_{jk}] + \varepsilon_{ijk}$$

where ε_{ijk} denotes an error term, and e_{ik} and m_{jk} are exporter and importer fixed effects, respectively. α_0 is a constant.

The estimates $\widehat{D_{ijk}^{-\theta}}$ then can be used to simultaneously solve for the equilibrium conditions [2] – [3] [[Anderson and Yotov, 2012](#)]. The corresponding estimates $\widehat{P_{jk}^{-\theta_k}}$ and $\widehat{\Pi_{ik}^{-\theta_k}}$, in turn, can be used for comparative statics and incidence analysis.

Obviously, the validity of the whole approach crucially depends on the consistency of the reduced-form estimation. Therefore, we first focus on this.

³The nonlinear programming approach of [Anderson and van Wincoop](#) should not anymore be applied, as it requires strong assumptions which are usually not fulfilled in practice [[Egger and Larch, 2012](#)].

3 Gravity Estimation, Poisson Pseudo Maximum Likelihood, and Adding-up

With the seminal paper of Santos Silva and Tenreyro [2006] a discussion started on the appropriate estimation of gravity trade models. Where the discussion on *aggregate* gravity trade models now seems to be settled, the discussion on *disaggregate* gravity trade models still goes on. The main problems are excess zeros and overdispersion⁴, which is why some researchers [Burger et al., 2009] propose zero-inflated count data models instead. However, both alternatives (i.e. zero-inflated Poisson/Negative Binomial Pseudo Maximum Likelihood (ZIPPML/ZINBPML)) suffer under model misspecification, i.e. if the data generating process does not follow a zero-inflated Poisson/Negative Binomial Distribution, estimates are biased [Staub and Winkelmann, 2012]; Negative Binomial Pseudo Maximum Likelihood even suffers under scale dependence, i.e. depending on the chosen scale of the endogenous estimates either converge against PPML or against Gamma Pseudo Maximum Likelihood [Bosquet and Boulhol, 2010].

Also the critic brought to PPML that it could not appropriately deal with excess zeros and overdispersion is not justified. Neither, PPML is biased by excess zeros [Santos Silva and Tenreyro, 2011], solely the constant cannot anymore be interpreted as before, enclosing now an additional zero-inflation parameter [Staub and Winkelmann, 2012], nor, is overdispersion really of a problem; it is standard to estimate the variance by means of a non-parametric sandwich estimator⁵, which converges asymptotically against the true variance.

All in all, from the estimation perspective, there is no reason why PPML should not be applied to *disaggregate* gravity trade models. Rather, PPML has an additional property which makes it even more preferable. PPML is the only estimator which fulfills the adding-up property, i.e. the sum of fitted trade flows (i.e. fitted output/expenditure) equals the sum of observed trade flows (i.e. observed output/expenditure) [Fally, 2012]. The usefulness of this property will become obvious in the next section.

4 Reduced-form Estimation and Structural Fit

Former remarks are just concerned with reduced-form estimation, however, as we said above, PPML has an additional advantage when it comes to a structural approach.

As Fally [2012] shows any fixed effects approach can already be used to derive multilateral resistance indexes from reduced-form estimation. However, for the construction of multilateral resistance indexes still fitted output and expenditure, and estimated fixed effects are required. If estimation would be consistent, there would be no problem. However, as we discussed above, only PPML is consistent.

⁴Overdispersion is given if the conditional variance is larger than the conditional expectation.

⁵Following Santos Silva and Tenreyro [2006], cluster-robust standard errors are now standard.

For fixed effects PPML, the construction of multilateral resistance indexes can even be simplified. Given the adding-up property of PPML, that fitted values always equal observed values, observed values can already be used to construct multilateral resistance indexes. Considering this, the unique solutions to the equilibrium conditions [2] and [3] are $\widehat{P}_{jk}^{-\theta} \equiv \frac{E_{jk}}{E_{0k}} \exp(-\hat{m}_{jk})$ and $\widehat{\Pi}_{ik}^{-\theta} \equiv E_{0k} Y_{ik} \exp(-\hat{e}_{ik})$, where E_{0k} denotes the sectoral expenditure of a reference country 0.

Compared to standard numerical methods [Anderson and Yotov, 2010], Fally's approach is by far easier to implement, just reduced-form fixed effects estimates are required, and comparative statics and incidence analyses are still consistent.

Standard comparative statics can directly be calculated, e.g. country-specific bilateral trade cost effects

$$[5] \quad \Delta \frac{X_{ijk}}{Y_{ik} E_{jk}} = 100 \times \left[\frac{\left(\widehat{D}_{ijk}^{-\theta_k} \right)^c \left(\widehat{\Pi}_{ijk}^{-\theta_k} \right)^c \left(\widehat{P}_{jk}^{-\theta_k} \right)^c}{\left(\widehat{D}_{ijk}^{-\theta_k} \right) \left(\widehat{\Pi}_{ijk}^{-\theta_k} \right) \left(\widehat{P}_{jk}^{-\theta_k} \right)} - 1 \right]$$

where superscript c indicates the counter-factual policy scenario.⁶

5 Conclusions

In this paper, we take up again the discussion of gravity trade model estimation in agriculture. We review recent literature to show that Poisson Pseudo Maximum Likelihood (PPML) is the only reliable estimator currently available. All other estimators are biased, as they suffer in particular from model misspecification and scale dependence [Prehn and Brümmer, 2011].

PPML has an additional advantage that has been so far neglected in the literature. It already allows for a structural fit of the gravity trade model. Given the adding-up property of PPML, fixed effects can be harnessed to directly deduce multilateral resistance indexes (i.e. general equilibrium effects) from a reduced-form estimation; hence, the advantages of a reduced-form estimation can be combined with that of a structural estimation. The approach developed by Fally [2012] is so promising as it should significantly ease comparative statics and incidence analysis; it should make gravity trade model estimation more tractable for trade policy analysis.

⁶For incidence analysis and derived measures as constructed home bias, domestic bias, and foreign bias see Anderson and Yotov [2010] and Anderson et al. [2012], respectively.

References

- J.E. Anderson and E. van Wincoop. Gravity with gravitas: A solution to the border puzzle. *The American Economic Review*, 93(1):170–192, 2003.
- J.E. Anderson and Y.V. Yotov. The changing incidence of geography. *The American Economic Review*, 100(5):2157–2186, 2010.
- J.E. Anderson and Y.V. Yotov. Gold standard gravity. Working paper, Boston College, Department of Economics, 2012.
- J.E. Anderson, C.A. Milot, and Y.V. Yotov. How much does geography deflect services trade? Working paper, Boston College, Department of Economics, 2012.
- C. Bosquet and H. Boulhol. Scale-dependence of the negative binomial pseudo-maximum likelihood estimator. GREQAM Working Paper No. 2010-39, GREQAM Groupement de Recherche en Economie Quantitative d’Aix-Marseille, 2010.
- M. Burger, F. van Oort, and G.-J. Linders. On the specification of the gravity model of trade: Zeros, excess zeros and zero-inflated estimation. *Spatial Economic Analysis*, 4(2):167–190, 2009.
- P.H. Egger and M. Larch. Estimating consistent border effects in gravity models with multilateral resistance. *The World Economy*, XX(XX):XXX–XXX, 2012.
- T. Fally. Structural gravity and fixed effects. Working paper, University of Colorado-Boulder, 2012.
- R.C. Feenstra. Border effects and the gravity equation: Consistent methods for estimation. *Scottish Journal of Political Economy*, 49(5):491–506, 2004.
- Z.U. Haq, K. Meilke, and J. Cranfield. Selection bias in a gravity model of agrifood trade. *European Review of Agricultural Economics*, XXX(XX):XXX–XXX, 2012.
- E. Helpman, M. Melitz, and Y. Rubinstein. Estimating trade flows: Trading partners and trading volumes. *The Quarterly Journal of Economics*, 123(2):441–487, 2008.
- R. Kotchoni and B. Larue. Asymmetric in the log-linear gravity model. FREIT Working Paper 439, Forum for Research in Empirical International Trade (FREIT), 2012.
- G. Philippidis, H. Resona-Ezcaray, and A.I. Sanjuan-Lopez. Capturing zero trade values in gravity equations of trade: A disaggregated sectoral analysis. In *EAAE 2011 Congress Change and Uncertainty, August 30 to September 2, 2011, Zurich, Switzerland*. European Association of Agricultural Economists (EAAE), 2011.
- S. Prehn and B. Brümmer. Estimation issues in disaggregate gravity trade models. Discussion Paper 1107, Georg August University Göttingen, Department for Agricultural Economics and Rural Development, 2011.
- S. Prehn and B. Brümmer. Payment decoupling and intra-european calf trade. Discussion Paper 12XX, Georg August University Göttingen, Department for Agricultural Economics and Rural Development, 2012.
- J.M.C. Santos Silva and S. Tenreyro. The log of gravity. *The Review of Economics and Statistics*, 88(4):641–658, 2006.

- J.M.C. Santos Silva and S. Tenreyro. Further simulation evidence on the performance of the poisson pseudo-maximum likelihood estimator. *Economics Letters*, 112(2):220–222, 2011.
- K.E. Staub and R. Winkelmann. Consistent estimation of zero-inflated count models. *Health Economics*, XXX(XX):XXX–XXX, 2012.
- B. Xiong and C. Sixia. Estimating gravity equation models in the presence of heteroskedasticity and frequent zeros. In *Agricultural & Applied Economics Association's 2012 AAEA Annual Meeting, August 12–14, 2012, Seattle, United States of America*. Agricultural & Applied Economics Association (AAEA), 2012.