Using a structural gravity model to assess the risk of livestock disease

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Introduction

- Idea: using livestock trade data and livestock disease incidence data estimate spatial spread of disease through international trade
- Livestock diseases spread through movement of animals
- Disease may act as a barrier to trade
- Gravity models are becoming a standard method for empirical trade modelling

UK Live animal trade

- The UK imports live animals from approx. 65 different countries
- Presence of disease leads to “enhanced import controls”
- However controls aren’t perfect
- value of imports in 2014 was approx. USD631 million (Comtrade)

Gravity models in Economics

Gravity models in Economics originally due to Tinbergen:

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

$$X_{ij} = g\frac{M_i M_j}{d_{ij}^2}$$

Trade flow is proportional to the product of two masses (GDP, population, other socio-economic factors) divided by distance squared.

Gravity models in Epidemiology and Ecology

- Gravity models have also been developed in epidemiology and ecology
- Simini, F., González, M. C., Maritan, A., & Barabási, A. L. (2012). A universal model for mobility and migration patterns. Nature, 484(7392), 96-100.
- Jongejans, E., Skarpaas, O., Ferrari, M. J., Long, E. S., Dauer, J. T., Schwarz, C. M., ... & Shea, K. (2014). A unifying gravity framework for dispersal. Theoretical Ecology, 8(2), 207-223.
- Balcan, D., Colizza, V., Gonçalves, B., Hu, H., Ramasco, J. J., & Vespignani, A. (2009). Multiscale mobility networks and the spatial spreading of infectious diseases. Proceedings of the National Academy of Sciences, 106(51), 21484-21489.

Gravity model in Agricultural Economics

- Koo, W. W., Karemera, D., & Taylor, R. (1994). A gravity model analysis of meat trade policies. Agricultural Economics, 10(1), 81-88.
- Reuben, J., Barau, A. D., & Akintunde, M. O. (2014). Determinants of live animals and animal products trade within the ECOWAS sub-region: A gravity model approach. Journal of Development and Agricultural Economics, 6(3), 132-139.
- Prehn, S., Brümmer, B., & Glauben, T. (2012). Structural gravity estimation & agriculture (No. 1209). Diskussionspapiere, Department für Agrarökonomie und Rurale Entwicklung, University of Goettingen.

Data

- I use UN Comtrade live animal trade data there are also some data available form HM Revenue and Customs and Defra.
- In addition I use the CEPII GeoDist data a standard data set for gravity modelling (Mayer, T. & Zignago, S. (2011) Notes on CEPII's distances measures : the GeoDist Database CEPII Working Paper 2011-25)
- Other data are taken from OIE World Animal Health Information Database (WAHID)
- use Data from 2012-2014 (3 years (I have more ca. 1500 obs.))
- Results in a panel data set of 197 observations

Structural Gravity

- Structural gravity models are derived from a consumer utility maximization model:

Consumers in country *i* maximise a CES utility function (Dixit-Stiglitz preferences) subject to a budget constraint.

$$U_i = (\sum_j \sum_k X_{ijk}^{\frac{\rho-1}{\rho}})^{\frac{\rho}{\rho-1}}$$

subject to

$$\sum_j \sum_k p_{ijk} D_{ij} X_{ijk} = I_i$$

where

$$X_{ijk}$$

is the quantity of a good of type k consumed in country i that originates in country j. In our case this is livestock of a particular type k, e.g. beef, chicken, pigs, etc. Country i is the UK.

Solving this and imposing general equilibrium conditions leads to the following (next slide)

Structural gravity

Gravity equation:

$$X_{ijk} = \frac{Y_{ik}}{\Pi_{ik}^{-\theta_k}} \times D_{ij}^{-\theta_k} \times \frac{E_{jk}}{P_{jk}^{-}\theta_k}$$

Multilateral Import Resistance:

$$P_{jk}^{-\theta_k} = \sum_j \frac{Y_{ik} D_{ij}^{-\theta_k}}{\Pi_{ik}^{-\theta_k}}$$

$$\Pi_{ik}^{-\theta_k} = \sum_i \frac{E_{jk} D_{ij}^{-\theta_k}}{P_{jk}^{-\theta_k}}$$

Estimation

Estimate

$$X_{ijk} = \frac{Y_{ik}}{\Pi_{ik}^{-\theta_k}} \times D_{ij}^{-\theta_k} \times \frac{E_{jk}}{P_{jk}^{-}\theta_k}$$

- using Pseudo-Poisson maximum likelihood with fixed effects ("Gold standard")
- This can be done using GLM (generalized linear models)

Egger, P. H., & Staub, K. E. (2014). GLM estimation of trade gravity models with fixed effects. Empirical Economics, 1-39.

- Various approaches to estimating the multilateral resistance terms (iterated methods, constrained maximum likelihood)

Fally's approach

Fally, T. (2015). Structural gravity and fixed effects. Journal of International Economics Volume 97, Issue 1, September 2015, Pages 76–85

To estimate the multilateral export and import resistance indices

$$P_{jk}^{-\theta_k} = \sum_j \frac{Y_{ik} D_{ijk}^{-\theta_k}}{\Pi_{ik}^{-\theta_k}}$$

$$\Pi_{ik}^{-\theta_k} = \sum_i \frac{E_{jk} D_{ijk}^{-\theta_k}}{P_{jk}^{-\theta_k}}$$

we can use

$$\hat{Y}_{ik} = \sum_j \hat{X}_{ijk}$$

and

$$\hat{E}_{jk} = \sum_i \hat{X}_{ijk}$$

Fally proves that

$$\hat{P}_{jk}^{-\theta_k} = \frac{\hat{E}_{jk}}{E_0} e^{-e_j}$$

and

$$\Pi_{ik}^{-\theta_k} = E_0 Y_{ik} e^{-m_i}$$

where m and e are the estimated import and export fixed effects respectively.

Results - First stage

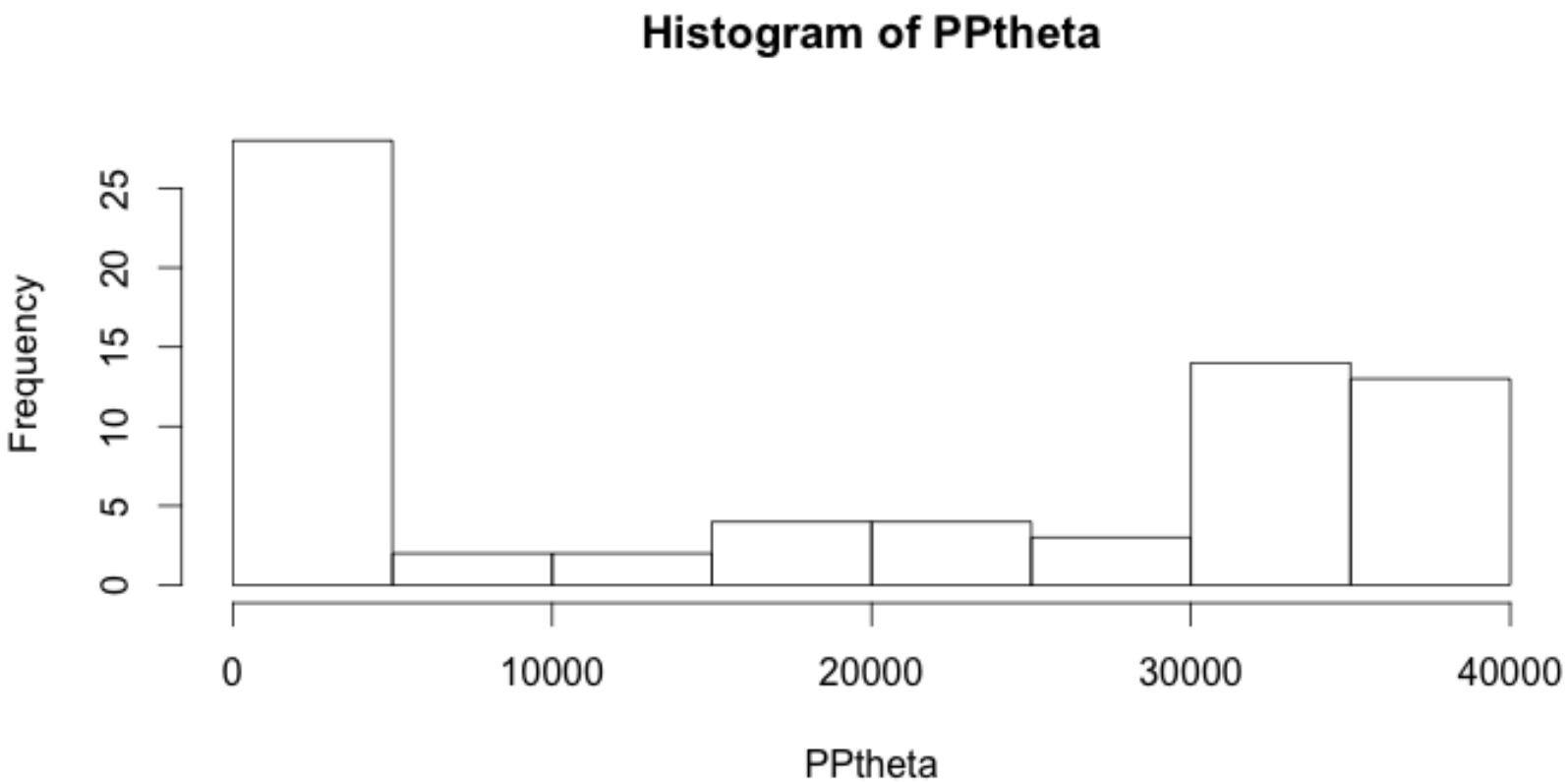
For the first stage I actually fitted using random effects with R's pglm package to account for unbalanced panel (alternative to using attrition dummies, see Wooldridge for a discussion of ways to handle unbalanced panel and attrition)

```
Maximum Likelihood estimation
Newton-Raphson maximisation, 14 iterations
Return code 2: successive function values within tolerance
Log-Likelihood: -63671496
7  free parameters
```

```
Estimates:
                 Estimate Std. error  t value  Pr(> t)
(Intercept)    1.482e+01  3.282e-01   45.155  < 2e-16 ***
ASF           -5.016e-01  1.914e-03 -262.022  < 2e-16 ***
contig         2.598e+00  2.285e+00    1.137 0.255489
comlang_ethno  8.170e-01  1.325e+00    0.616 0.537622
colony         1.728e+00  1.203e+00    1.436 0.150969
distcap       -1.991e-04  5.802e-05   -3.432 0.000598 ***
sigma          2.265e-01  2.860e-02    7.921 2.36e-15 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘
```

Results - second stage

Estimated using Fally's approach based on fixed effects without attrition dummies (there are problems in trying to use attrition dummies in this type of set-up). You need to use fixed effects here to extract parameters for computing the second-stage structural equations. Estimation was done using R's glm package.



Conclusion

- Disease is a factor leading to resistance to exports for a number of countries
- Need to extend empirical work to cover more diseases
- Need to consider a case of disease incursion (using joint dummies to measure flow of pathogen)
- So far this is a proof of concept that the method works.
- I have only scratched the surface of the available data
- Incorporating trade resistance terms back into the original estimated gravity equation allows the analysis of the impact counter-factual scenarios on imports, e.g. impact of disease outbreak in country X on the UK.