

Revisiting Commodity Trade Patterns Amidst Food System Shocks: Lessons from Structural Gravity with Counterfactual Experiments

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Abstract

The structural gravity model predicting bilateral trade is often considered one of the most successful models in international trade, not only because it produces some of the most consistent empirical findings in economics, but also because of its compact specification making it appealing to estimate the impact of trade policy or trade liberalization scenarios. However, less is known about the performance of structural gravity when conducting counterfactual experiments. This study reviews the development and implementation of the structural gravity model applied to land-based commodity trade, highlighting its strengths and limitations. We then conduct a pseudo-validation exercise by examining the predictions of structural gravity for bilateral commodity trade flows and other market variables when conducting counterfactual trade policy experiments. Specifically, we go back to a 2016/17 marketing year baseline (i.e., initial equilibrium) of bilateral trade, crop output and domestic use for wheat, corn, rice and soybeans and estimate the model's parameters. Next, we impose trade costs (i.e., retaliatory tariffs) that match the tariff levels and trade frictions China applied in its retaliation against U.S. crop products during the 2018/19 U.S.-China trade dispute. We then solve the GE structural gravity model for new equilibrium multilateral resistance terms, crop output, land use, farm gate and export prices, and domestic use following China's retaliatory tariffs. Finally, we compare the predictions of the structural gravity simulation to realized market outcomes actually observed during the trade dispute.

Key words: Structural gravity, bilateral trade, validation, trade dispute, Russia-Ukraine conflict

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Background

The structural gravity model predicting bilateral trade is often considered one of the most successful models in international trade (Head and Mayer 2014), not only because it produces some of the most consistent empirical findings in economics, but also because of its compact specification making it appealing to estimate the impact of trade policy or trade liberalization scenarios (Baier, Yotov and Zylkin 2019; Grant et al. 2021; Luckstead 2022; Heid and Stahler 2024; Peterson, Grant, Roberts and Karov 2013; Grant and Boys 2012).¹

Recent advances in the theoretical and empirical trade literature, originally pioneered by Anderson and van Wincoop (2003) and expanded to become computational “structural gravity” by Yotov, Piermartini, Monteiro and Larch 2016, Anderson and Yotov (2016), Anderson, Larch and Yotov (2018) and others, have advanced this model from one based purely on *ex-post* statistical and econometric regressions that fit the data remarkably well, to a much richer structural framework that is at the center of new quantitative trade models to conduct *ex-ante* “what-if” counterfactual scenarios. Arkolakis, Costinot and Rodriguez-Clare (2012) show succinctly that a large class of quantitative trade models yield the familiar gravity equation (see also Head and Mayer 2014). This includes models based on Armington preferences (Anderson and van Wincoop 2003), Ricardian specialization (Eaton and Kortum 2002), monopolistic competition (Krugman 1980) and heterogeneous firms (Melitz 2003).

Moreover, while most structural gravity studies offer estimates that demonstrate its success with aggregate data, Anderson et al. (2015) demonstrate that gravity works very well with services data, Borchert et al. (2022) finds strong goodness of fit across 170 sectors covering agriculture, mining, manufacturing goods, and services, and Grant et al. (2021) and Arita et al. (2022) find that structural gravity performs well on higher frequency monthly bilateral trade data when researchers need to examine within-year trade reorientations such as those due to the U.S.-China trade dispute and the Covid-19 pandemic, respectively.

Objectives

Despite this success, less is known about the performance of structural gravity when conducting counterfactual experiments. As academic and modeling communities revisit the assumptions by which we think about, and model bilateral trade for food system resiliency, important questions remain about the role of structural gravity models in this debate. For example, after estimating the model’s structural parameters using historical data, how well does the model match realized bilateral trade patterns when we simulate an *exogenous* shock or conflict scenario and solve for counterfactually predicted market outcomes? What inferences can structural gravity tell us about other key market outcomes such as crop output, farm-gate prices, consumption patterns and land use?

The purpose of this paper is to review the development and implementation of the structural gravity model applied to land-based commodity trade, highlighting its strengths and

¹ As Heid and Stahler (2024) note, a simple google search for “gravity” and “international trade” yields about 126,000 results. However, it may not have the worldwide prominence of GTAP. A simple google search for “GTAP” and “international trade” yielded 244,000 results.

limitations. We then turn to a pseudo-validation exercise by examining the predictions of structural gravity for bilateral commodity trade flows and other market variables when conducting counterfactual trade policy experiments. We conduct these comparisons in a similar vein as computable general equilibrium (CGE) researchers do when validating simulation experiments (for e.g., using the Global Trade Analysis Project (GTAP) model) (Dixon and Rimmer 2013). Dixon and Rimmer (2013) highlight two critical components when validating CGE models: (i) historical simulations in which the model is forced to track history, and (ii) testing the model's ability to reproduce outcomes for endogenous variables given truly exogenous variables or shocks.

Policy Scenarios Considered

Part of the elegance and appeal of quantitative trade and structural gravity models is that they are based on econometrically estimated parameters that match the country, product, and time-period aggregation of the shock. The quantitative simulation step then uses these “estimated” parameters to simulate a new (often single endowment based) equilibrium by solving the GE structural gravity model. To evaluate the predictions from structural gravity, we go back to a 2016/17 baseline (i.e., initial equilibrium) of bilateral trade, crop output and domestic use for wheat, corn, rice and soybeans. Next, we impose trade costs (i.e., retaliatory tariffs) that match the tariff levels and trade frictions China applied in its retaliation against U.S. crop products during the 2018/19 U.S.-China trade dispute. We then solve the GE structural gravity model for new equilibrium multilateral resistance terms, crop output, land use, farm gate and export prices, and domestic use following China's retaliatory tariffs. Finally, we compare the predictions of the structural gravity simulation to realized market outcomes actually observed during the trade dispute. As an alternative, non-policy-induced experiment, we also consider the more recent shock to crop output and commodity exports from the conflict in Ukraine.

Data

Bilateral trade values and volumes were assembled from Trade Data Monitor for a balanced 70x70 matrix covering the years 2016-2022 for wheat, corn, rice and soybeans. TDM provides trade values and quantities from origin to destination in HS6-digit products. A key input for structural gravity and counterfactual experiments is the inclusion of inter- and intra-national trade to ensure we have a complete demand system and output represented for welfare analysis. To facilitate this, we use the agricultural structural gravity database maintained by the Center for Agricultural Trade at Virginia Tech. Along with international trade data for each crop, this database also appends a complete and balanced set of intra-national trade flows using USDA's Production, Supply and Distribution (PSD) commodity balance tables for production, export, domestic use, and stock changes.

Potential to Stimulate Discussion

Evaluating the validity of the structural gravity modeling framework for crop-based commodity trade will provide new insights about the extent to which this model fits in a broader class of computable partial and general equilibrium models to simulate *ex-ante* counterfactual experiments. Given the increased need to understand the responsiveness of bilateral trade as a

potential adaptation mechanism amidst significant shocks to agricultural markets over the last 5-6 years, a more complete understanding of structural gravity predictions will help policy makers design effective strategies to enhance the resiliency of global food systems and is likely to stimulate a lively discussion among GTAP conference participants.

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