Economic Modelling 55 (2016) 115–126

Contents lists available at ScienceDirect

Economic Modelling

journal homepage: www.elsevier.com/locate/ecmod

A new trade network theory: What economists can learn from engineers

Michael Hübler*

Leibniz Universität Hannover, Institute for Environmental Economics and World Trade, Königsworther Platz 1, 30167 Hannover, Germany

ARTICLE INFO

Article history:
Accepted 5 February 2016
Available online

Keywords:
International trade
Gravity model
Network theory
Optimal tariff
Business cycles
Propagation of shocks

ABSTRACT

This paper introduces a new trade model type combining the gravity model used by economists and network analysis methods used by electrical engineers. The new model type contributes to the trade network literature by enabling the description of complex dynamic processes, such as the propagation, overlap and cancellation of shocks and business cycles. This opens many possibilities for future policy applications with disaggregated model regions and sectors. The paper furthermore contributes to trade theory by deriving a straightforward rule for the optimal tariff respectively trade barrier. Calibrating the model to the World Input-Output Database (WIOD), the optimal trans-Pacific trade barrier between North America and Asia is estimated to be one third of the current trade barrier. The analysis identifies strong repercussions on global trade caused by increased trans-Pacific trade.

1. Introduction

This paper describes a novel way of modeling international trade, taking into account the spatial as well as the time dimension of trade. It describes the real-economic connections between trading partners in a global trade network. For this purpose, it draws on the well-known and empirically valid[1] gravity model, which states that trade flows increase in the GDPs (gross domestic products) of the trading partners and decrease in the distance between them.[2] It transfers methods for describing and analyzing complex networks from the domain of electrical engineering[3] to the domain of economic modeling.[4] In contrast to other large-scale economic models, these methods enable a numerical model solution as well as a strictly algebraic solution of a static setup or a dynamic setup including cyclical or transitional dynamics.[5] The methods are also less restrictive than the constant elasticity of substitution (CES) functions and the corresponding uncertain elasticity parameters used in standard Armington (1969) trade models, i.e., they require no specific assumptions on functional forms.

The following paper relates to the literature studying the World Trade Web (WTW) with the help of typology, statistical indicators, network analysis or graph theory, known from statistical physics and social networks.[6] Unlike this literature, the following paper does not analyze the global trade network in a descriptive statistical way but by setting up and analyzing a full-fledged economic model. Hereby, it extends the tool box of computable general equilibrium (CGE) modeling[7] based on neoclassical trade theory.[8] Compared to Armington-based CGE models[9], the model proposed in the following can be solved algebraically so that it is directly observable, in which fashion a local shock propagates through the remaining network. To obtain a numerical solution, the model can be calibrated to a benchmark situation defined by trade and GDP data. Following

* Tel.: +49 511 762 19569; fax: +49 511 762 2667.
E-mail address: huebler@iuw.uni-hannover.de (M. Hübler).

1 McCleery and DePaolis (2014, p. 200); Krugman et al. (2014, ch. 2).

2 For theoretical foundations and a review see Anderson (1979, 2011); Anderson and van Wincoop (2003). The following analogy applies to the economic and the physical gravity law: Economies' GDPs refer to objects' mass, and a price differential creates a force comparable to the gravitational force. A larger distance reduces this force in both cases. In the first case, the force drives trade in goods, in the second case, the force moves objects.

3 See, for example, Clausert and Wiesemann (1993a; 1993b).

4 The following analogy applies to electric networks and trade networks: A trade flow refers to an electric current, a price differential refers to a differential in electric potential (voltage), and a trade barrier refers to an electric resistance.

5 The algebraic dynamic analysis extends the scope of the literature on modeling economic growth, cf. Aghion and Howitt (2009), which usually describes and compares steady state properties.

6 Fan et al. (2014); De Benedictis and Tajoli (2011); Fagiolo et al. (2010); Serrano et al. (2007); Li et al. (2003) and others; see Section 2.

7 For an overview see McCleery and DePaolis (2014).

8 For an introduction see Krugman et al., (2014, chs. 3–6).

9 Ackerman and Gallagher (2008); Hertel et al. (2007) for critical discussions of the gains from trade.

http://dx.doi.org/10.1016/j.econmod.2016.02.009

the CGE literature, the calibrated model can be used to compare counterfactual scenarios, in which model parameters are changed, to the benchmark calibration.

The new model type proposed in this paper is composed as follows. As in other trade network representations, countries or regions engaged in international trade are represented by knots (nodes or vertices), and international trade is represented by the line linking two knots. In contrast to a number of existing network analyses, the trade links are always directed, either in the form of bilateral trade or net trade flows. Following the gravity model, each country or region is characterized by its GDP (its economic mass). In the existing trade network representations, a trade link is often weighted by the corresponding trade volume. In the following new model type, the link is (inversely) weighted by the corresponding trade resistance, taking into account the distance between two trading partners and any trade barriers as in an extended gravity model, while the corresponding trade volume emerges endogenously. Hence, in the numerical representation, the trade resistances are calibrated so that the benchmark trade volumes and GDPs are replicated. This is a crucial difference to the existing trade network representations where trade volumes are exogenously given by the data and analyzed with the help of statistical indicators. In the following exemplary analyses, trade is defined at an aggregate macro-economic level without taking into account different goods or sectors. This approach follows the network analysis literature and has the advantage that aggregate trade flows measured in a specific currency unit can be treated as a homogeneous current throughout the network. Similar to the notion of the "multilateral resistance"[10], single trade resistances can be aggregated to an overall substitute resistance for the whole network or a part of the network. Then a specific trade flow depends on the trade resistance of the link, where it passes through, relative to the overall trade resistance.

So far, the effects, overlaps and interactions of policies within the complicated global trade network have hardly been understood. The following model enables such an analysis by applying the superposition principle, i.e., trade flows are analyzed separately and eventually summed up. For the comparative static or dynamic network analysis, it is necessary to define at least one exogenous driver within the network. The driver can be a trade flow or a GDP value. The remaining trade flows and GDP values associated with the lines and knots then emerge endogenously. It is assumed that GDPs and trade flows interact via international prices (price differentials) for traded goods.[11] A country with a larger GDP has more power on international markets and hence a lager impact on international prices and trade volumes, similar to the well-known concept of the terms-of-trade. Changes in traded volumes in turn create stronger leverage effects on prices and GDPs of large economies than of small economies. Based on these premises, the model can be solved by assuming balanced trade budgets and a closed system (without unexplained gains or losses of economic values) as in other general equilibrium models plus a no-arbitrage condition. In mathematical terms, we need to solve a linear equation system of N equations and N unknowns.

For a dynamic analysis, cyclical behavior representing business-cycles can be modeled by replacing real numbers by complex numbers.[12] Complex numbers provide a convenient way of describing sine-shaped behavior characterized by its magnitude and phase (angle). Likewise, transitional behavior between two economic equilibria or the propagation of economic shocks can be modeled with the help of the Laplace transformation. In the dynamic setup, the static trade resistance can be accompanied by a dynamic trade resistance that represents adjustment costs and dampens dynamic responses.[13]

The model is calibrated to the world regions Europe, North America, Asia and the rest of the world. The model applications address two important aspects of the current economic policy debate. First, the aftermath of the economic crisis from the year 2007 onwards has shown that more research is necessary to understand how economic shocks propagate through the global economic network and affect other economies (cf. Section 2.2). To this end, the model analysis assumes an exogenous sine-shaped or abrupt price (GDP) shock[14] and inspects the endogenous effects on trade of other economies. Second, regarding the Transpacific Partnership (TPP) and the Transatlantic Trade and Investment Partnership (TTIP) more research is necessary to better understand how regional trade policies affect the global economic network and hence other economies.[15] The model represents any barriers to trade including non-tariff barriers in the form of a static trade resistance. Accordingly, the trade resistance between Noth America and Asia is reduced, or alternatively an increased trade flow between Asia and America is assumed in order to mimic a trans-Pacific trade agreement.

The model analysis yields the following insights. First, regional changes in trade can create strong repercussions throughout the global trade network. If, for example, Asia's exports to North America increase by 10%, North America's direct exports to Asia will increase by only 5%, while the trade flow from North America to Asia via Europe will increase by around 25% and the trade flow from North America to Asia via the rest of the world will increase by around 38%. This result implies that there are lower impediments to American exports to Europe and the rest of the world than to Asia. As a result, most of the additional exports induced by higher American imports from Asia are absorbed by Europe and the rest of the world (no matter measured in relative or absolute terms).

Second, specific trade connections can be shielded from the trade flux around them. For example, a reduction of the trade barrier between Europe and Asia to about one half can create a situation, in which the rest of the world, in particular Africa, is shielded from shocks affecting international goods markets. The reason is that the bulk of global trade occurs between America, Europe and Asia. Consequently, shocks mainly propagate between these regions while trade between Europe and Africa is hardly affected by the shocks surrounding it.

Third, fluctuations like business cycles can overlap in such a way that they obliterate or exacerbate the overall resulting trade flow. If the business cycles of two economies create trade flows that move in parallel, based on the superposition principle the resulting sum of the two trade flows will be larger than each single trade flow. If, on the contrary, the two business cycles are exactly counter-cyclical, the resulting trade flows will mitigate or cancel out each other. Trade flows have in turn repercussions on the GDPs of the trading partners. This implies, too, that shocks or policies can interact so that unanticipated economic outcomes can emerge which are much bigger or smaller than the original single shocks. This complicates estimates of the economic effects of policies or shocks in a complicated network.

10 Akin to Anderson and van Wincoop (2003).

11 Kose (2002) for fluctuations of international prices and business cycles and Li et al. (2003) for the synchronization of GDP cycles and world trade.

12 Backus et al. (1994); Frankel and Rose (1998); Kose and Yi (2006) for business cycles and trade.

13 Gagnon (1989); Feenstra and Lewis (1994); Furusawa and Lai (1999) for adjustment costs and trade.

14 This paper solely deals with real-economic effects. In terms of real-economic effects, the economic crisis from 2007 onwards showed that international financial and real-economic connectivity go hand in hand and that trade reacts sensitively to GDP shocks.

15 The Economist (2015a; 2015b); Aichele et al. (2014) for the policy debate and an assessment.