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Interfaces with Other Disciplines

Ranking trade resistance variables using data envelopment analysis☆

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ABSTRACT

In the context of Justus von Liebig's Law of the Minimum, this study assesses the impacts that trade barriers have on trade resistance between United States (U.S.) manufacturing industries and their trade partners. An undesirable trade resistance model is presented, where trade barriers are (undesirable) inputs into the production of the (undesirable) output, trade resistance. It is then presented how Johansen's notion of Capacity is utilized to assess trade barriers' impacts. Estimation takes place by employing Data Envelopment Analysis (DEA). Results suggest that U.S. trade partners' port logistics are the most limiting trade barrier for the U.S. manufacturing industries, followed by the distance between the U.S. and its trade partners, the tariff imposed by the U.S., and the tariff imposed by the trading partner.

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1. Introduction

World Trade Organization statistics show world merchandise exports' value varying from about 2 trillion dollars in 1980 to over 18 trillion dollars in 2012. In terms of the United States (U.S.), according to the Census Bureau's Foreign Trade Division, U.S.'s exports value has increased from approximately 271 billion dollars in 1980 to about 2.2 trillion dollars in 2012 while the value of imports has increased from about 291 billion dollars in 1980 to approximately 2.7 trillion dollars in 2012. Although the U.S. is increasingly dependent on trade with other countries, impediments to trading goods and services, or trade resistance, still exist. In an effort to lessen these impediments, mutually beneficial trade agreements between the U.S. and other nations are negotiated and agreed upon. Even so, trade resistance still persists. Therefore, when commencing trade negotiations, or refining existing trade agreements, it is essential for policy makers to be well informed of the factors that impact trade the most, in order to maximize the welfare gains from trade.

Drawing upon trade data for U.S. manufacturing industries, this study seeks to investigate which trade resistance variable, or trade barrier, impacts trade resistance the most between the U.S. manufacturing industries and their trading partners. A desired outcome is to rank the trade resistance variables from the most impactful to the least impactful in terms of trade resistance. The main objective is to shed light on the trade barriers that would generate the largest increases in trade flows when lessened. Why are increases in trade desirable? Standard International Economics theory suggests that when countries engage in trade with each other, each country's production possibilities frontier expands, in essence improving standards of living.

In this study a theoretical model of trade resistance is formulated in a production framework. Trade resistance variables, or trade barriers, are considered undesirable inputs that yield the undesirable output, trade resistance. Then, in the spirit of Justus von Liebig's *Law of the Minimum*, Johansen's notion of *Capacity* is placed into this framework. Estimation takes place via non-parametric Data Envelopment Analysis (DEA), which will show which trade resistance variable, or trade barrier, yields the most trade resistance. Using this methodology, a ranking of trade resistance variables is obtained based on their respective impacts on trade resistance. Before proceeding to the main body of this paper, additional details will be presented on Justus von Liebig's *Law of the Minimum* and Johansen's concept of *Capacity* along with their significance for this paper.

To comprehend the implications and conclusions of this study is to understand Justus von Liebig's *Law of the Minimum*. The *Law of the Minimum* states that growth (of a biological plant) is given by the scarcest or most limiting nutrient, or alternatively, that increasing abundant nutrients does not yield as much growth as increasing the scarcest nutrients. This *law* is applied here but in the international trade arena, where the goal is to explore which undesirable trade resistance variable ("nutrient") is the most limiting in terms of undesirable trade resistance ("plant growth"), or alternatively, which variable creates the most trade resistance.

In order to apply the *Law of the Minimum* to this study, this paper makes use of the concept of *Capacity* which is defined by Johansen (1987) as "… the maximum amount that can be produced

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per unit of time with the existing plant and equipment provided that the availability of variable factors is not restricted.” In other words, in a production framework, inputs will be divided into two categories-fixed and variable. The maximum potential output will therefore be given by the variable inputs, which can vary to any level. In a *Law of the Minimum* context, variable inputs can be seen as the limiting factors, the ones that can cause increases in output growth the most. In a similar fashion, in this paper, trade resistance variables are separated into fixed and variable. For example, the *distance* variable could be held as a fixed input, while the variable *tariff* would be an input that is variable. Through DEA estimation the impact of the variable *tariff* on trade resistance would be assessed. The roles could then be reversed to investigate *distance*’s impact. In the end, a ranking of trade resistance variables would be established based on the impacts that each of these variables have on trade resistance.

Knowing which trade resistance variable is the most restrictive is important because U.S. trade policy could then be appropriately targeted. For example, previous studies (Anderson & van Wincoop, 2004; Novy, 2006; Novy, 2009) have found that the trade resistance variable, *tariff*, does not affect trade resistance greatly. Wu (2012) found similar results in the case of tariffs, but the trade resistance variable *distance* was found to be the most impactful on trade resistance. As a result, it would be unwise to direct policy efforts towards tariffs, when other trade resistance variables have relatively greater economic impacts.

The research in this paper could also benefit institutions in the world trade arena devoted to reducing trade resistance. For example, if *distance* between the U.S. and its trading partners is a major factor influencing bilateral trade, then Research & Development efforts could be directed to things such as improvements in infrastructure, and advances in transportation technologies, i.e. fuel efficiency. At the same time, this study’s findings could also steer academic research in a new direction, by incentivizing university research to focus on areas with the greatest potential impact on reducing trade resistance, research that could be beneficial to policy makers when deliberating trade negotiations and trade agreements.

According to the International Trading Centre, there are some interesting trade patterns to notice around the world. India’s exports to the United States are 13 percent of its total exports, to Brazil 2 percent, to the United Kingdom 3 percent, but to Pakistan, Myanmar, Nepal, Bhutan (some neighboring countries) exports are a total of 2 percent combined. In India’s case, distance does not seem to be an important trade resistance factor. In contrast, Mexico’s exports to the United States are 78 percent of its total exports, while exports to Western Europe less than 4 percent. In these cases, and possibly others, the patterns of trade could be associated with the history between nations. For example, India’s colonial ties to the United Kingdom and its historical relationship with Pakistan are extensive, and its trade patterns may be a reflection of this. Inducing India to trade with relatively closer nations might be better addressed through political and social avenues, rather than policy instruments such as tariffs. Therefore, it is important for policy makers to know which trade resistance variables are the most restrictive, so that trade policy could then be formulated in a way that it could have the greatest potential impact on trade, and in turn on standards of living.

Trade resistance as an international trade concept has its roots in the gravity equation which itself has its beginnings in Tinbergen (1962). The author specified bilateral trade flows as a function of country sizes (given by their gross national product) and trade resistance between the countries in question (Helpman, Melitz & Rubinstein, 2008). Therefore, trade resistance can be seen as all other factors that influence bilateral trade flows, excluding country sizes. Trade resistance factors may include the distance between countries, geographic variables such as common borders, whether the nation is an island, whether the nation is landlocked, tariffs, political and institutional variables, and any other factors that could influence bilateral trade flows.

Past studies investigating trade resistance included Hausman, Lee and Subramanian (2005) and Wu (2012). These papers have analyzed the impacts of trade resistance variables on calculated trade costs indices. Econometric estimates in these papers yield statistically significant results in line with theoretical predictions, i.e. positive relationships between trade costs and these variables. Wu (2012) also calculated elasticities of the impacts on trade costs, which show the economic significance of the statistical results. This study, by employing a different methodology i.e., Data Envelopment Analysis, will also seek to investigate which trade resistance variables are the most restrictive, with the goal of ranking these variables and relating them with past studies.

Studies that have used similar methodology as this paper’s extend across diverse topics of research. For example, Wang, Färe and Seavert (2006) looked at the revenue capacity efficiency of pear trees. Färe, Wang, Schubert, Bronson, Johnson (2009) analyzed the limiting nutrients in peanut production, and Färe, Grosskopf, Lundgren, Marklund, Zhou (2013) looked at the limiting capacity of pollutants with an application to the Swedish paper producing industry. Additionally, Subhash (2015) investigated the minimum long run average cost along with the output level where this minimum is achieved utilizing U.S. state level manufacturing production data. Sahoo and Tone (2009) used capacity utilization and DEA with an application to Indian banks, and Valdmanis, Bernet and Moises (2010) assessed emergency preparedness of Florida hospitals.

The literature on DEA is extensive, and to conserve time and stay on point, only a handful of studies will be mentioned here. For example, Färe and Grosskopf (1983) have presented two measures of output efficiency and illustrated those using DEA techniques. Färe and Li (1998) presented a discussion on inner approximations to technology using DEA, and Färe and Grosskopf (2004) showed an approach to modeling a polluting technology using DEA.

This paper is organized as follows. Section 2 presents the theoretical framework. The estimation procedure is laid out in Section 3. The data used in this study is presented in Section 4. Section 5 presents the estimation results and discusses them, while Section 6 summarizes and concludes.

2. Theoretical framework

2.1. Trade resistance function

Undesirable trade resistance will be specified as a function of the undesirable trade resistance variables, meaning these variables will yield the level of trade resistance. The trade resistance level will be represented by $r \in \Re_+$, and the trade resistance variables will be represented by a vector $q, (q_1, \ldots, q_n),\ with\ q \in \Re^N_+$. A trade resistance function, $T(q)$, can then be specified as a function of the trade resistance variables as follows,

$$T(q) = \max_r \{r : q \text{ generates } r,\ q \in \Re^N_+, r \in R_+\} \quad (1)$$

This function therefore represents the bilateral trade resistance level given by the trade resistance variables. Also, the set bounded from above by $T(q)$ can be defined as,

$$S = \{(q, r) : T(q) \geq r, q \in \Re^N_+, r \in R_+\} \quad (2)$$

As an illustration and assuming a linear trade resistance function, Fig. 1 portrays the relationship between trade resistance, r, and the trade resistance variable, q. In the figure, r_1 is the level of trade resistance given by the q_1 level of the resistance variable q. Set S (given by q and r) is also portrayed in this figure, as the space up to and including the trade resistance line.

Certain properties are imposed on this framework. These properties, are outlined next as follows: