# Three Essays in Empirical Economics

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**Abstract**

This dissertation consists of three essays. The first essay estimates a demand function for compressed natural gas as a fuel substitute to diesel fuel for firms with hybrid fleets. The data is from the Energy Information Administration, for the years 1989 to 2009, for 47 states. Results show that an increase in the price of diesel fuel by $0.10 will increase compressed natural gas demand by 5.59%.

The second essay focuses on regional trade agreements (RTAs). A number of studies have found that regional trade agreements (RTAs) significantly increase members' trade flows. While recent studies have begun to explore the reasons for this, none have examined whether the RTA trade effect varies systematically with the number and type of policy areas covered by the agreement. While the empirical trade literature has shed considerable light on the trade-creating ability of RTAs (Grant & Lambert, 2008), much less is known about why these agreements are so successful. In this study we draw on a new database from the World Trade Organization of trade policy areas covered by RTAs to examine whether the degree of trade liberalization is an important determinant of the RTA trade effect. An augmented, theoretically consistent gravity equation is developed to explore the effects of RTAs on trade conditional on the policy areas they include. In particular, we investigate two policy areas that are particularly important for agricultural trade, sanitary and phytosanitary measures (SPS) and technical barriers to trade (TBT). The results suggest that harmonization of non-tariff measures inside RTAs matters: Agreements that liberalize these policies increase members' agricultural trade by an additional 62 percent compared to agreements that do not. We conclude that studying the components of RTAs – in particular, the policy areas covered by these agreements – is important when analyzing the determinants of RTA trade

effects.

The third essay uses Bayesian Model Averaging (BMA) to study the effect of membership in the General Agreement on Tariffs and Trade (GATT), the predecessor to the World Trade Organization (WTO) and the WTO on trade flows. Existing GATT/WTO literature is not univocal as to whether membership in the GATT/WTO increases trade flows. Bayesian model averaging (BMA) is used in the presence of theoretical uncertainty, in this study, to address whether membership in the GATT/WTO plays a role in the gravity model. Several datasets are examined: a dataset of a previous study; and two datasets compiled for this study, world trade and agricultural trade. Results show for all three sets of data. That membership in the GATT/WTO does belong in the gravity equation and increases trade flows.

# DEDICATION

Dedicated to my mother and father.

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# CHAPTER 1

# INTRODUCTION

The following chapters focus on three different fields in economics: environment and energy economics, international trade, and applied econometrics.

The first chapter stands on its own, examining the preferences for natural gas versus diesel fuel as a source of energy to power vehicles. It focuses on the importance of alternative fuel vehicles, in particular natural gas vehicles, and the preferences of commercial firms for natural gas vehicles versus conventional diesel-fueled vehicles. The study examines firms with hybrid fleets and their demand for natural gas fuel, in particular compressed natural gas (CNG), as a substitute for diesel fuel. The study also examines policy implications of technological advancements of "horizontal drilling" and the recent discovery of natural gas deposits in the United States, leading to an increase in the supply of natural gas.

The second two chapters focus on a trade model, the gravity model. The gravity model is a popular tool used to estimate trade flows between nations. It is a function of GDPs, trade barriers or facilitators, as well as multilateral resistance terms, which are discussed in further detail in chapter three. The third chapter examines the importance of regional trade agreements (RTAs) in the gravity model. In particular, it attempts to explain why RTAs have been so successful in increasing trade flows. The study examines fourteen policy areas that can be included in an RTA, focusing on sanitary and phytosanitary measures (SPS) and technical barriers to trade (TBT). The study explores two data sets: world trade and agricultural trade.

The third chapter also focuses on the gravity model, taking an innovative econometric approach in estimating the gravity equation with Bayesian statistics, a new statistical approach that is still new to the gravity model literature. Bayesian Model Averaging (BMA) is used to estimate which trade barriers are most important in the gravity model. In particular, the study focuses on membership in the General Agreement on Tariffs and Trade (GATT), the predecessor to the World Trade Organization (WTO) and the WTO. Existing studies are not univocal about membership in the GATT/WTO increasing trade flows. BMA is used in the presence of model uncertainty, to address whether membership in the GATT/WTO belongs in the gravity model. This chapter examines three data sets: a combined dataset of two previous studies on membership in the GATT/WTO; and two datasets compiled for this study, world trade and agricultural trade.

CHAPTER 2

# ESSAY 1: FIRMS' DEMAND FOR NATURAL GAS AS A SUBSTITUTE FOR DIESEL FUEL

## 2.1 Abstract

This paper estimates a demand function for compressed natural gas as a perfect fuel substitute to diesel fuel for firms with hybrid fleets. Our data is from the Energy Information Administration, for the years 1989 to 2009, for 47 states. We find that an increase in the price of diesel fuel by $0.10 will increase compressed natural gas demand by 5.59%. We also look into policy implications from the increase in the supply of natural gas due to technological advancements, we find that these hybrid fleets' demand is increased at equilibrium due to the technological advancement.

## 2.2 Introduction

### 2.2.1 Natural Gas as a Fuel

The use of natural gas in ground vehicle engines is not new. First developed in 1860, the natural gas engine actually preceded the gasoline engine. But, owing to the relative cheapness of the extraction and refinement of oil, interest in the natural gas vehicle (NGV) lagged that of the gasoline-powered vehicle for years; in fact, NGVs were not used in the United States until the 1960s[1]. The tides have turned in recent years, however, as the burgeoning economies of countries such as China and India, have conspired to push oil prices higher due to an increase in demand for the fuel, making the NGV a more attractive alternative. There are also significant non-price benefits (environmental friendliness, reduction of dependence on foreign oil) of using natural gas to power vehicles instead of petroleum fuels. But, despite these developments, the demand for the natural gas fuel that powers NGVs has not been thoroughly examined. In this paper, we focus on a specific kind of natural gas fuel, compressed natural gas (CNG). We calibrate the demand for CNG, and analyze policy implications associated with an expected increase in the supply of natural gas due to recent technological breakthroughs such as horizontal drilling.

A large number of commercial use vehicles already embrace CNG. UPS, for example, has invested in alternative vehicle technology and explored viability of new fuel types since the 1980s ("Press Releases", 2012). In particular, UPS fleets have used CNG to power their vehicles since 1989 ("Press Releases", 2012), and there are currently more than 1,000 CNG-powered UPS vehicles. Waste Management is another company that prides itself with a focus on sustainability. Waste Management fleets currently include nearly 1,000 vehicles fueled by liquified natural gas (LNG) and CNG ("Sustainability report update", 2012). Lastly,

[1] "Washington Gas - Natural Gas Vehicles" (2013)

11,000 transit buses, 3,000 school buses, 15-17,000 medium-duty vehicles, and 30,000 light-duty vehicles in federal, state, and local governments are powered by natural gas ("NGVA", 2011). These vehicles use petroleum-based diesel fuel (DF) when not using CNG, so CNG is de facto a perfect substitute for diesel; that is, firms that use large trucks and buses are the ideal candidates to switch from DF to CNG for both price and non-price advantages.

One such non-price advantage is the general environmental implication relative to conventional fuels. For example, while diesel-powered vehicles emit significantly (10-20%) less greenhouse gases than comparable gasoline vehicles , natural gas vehicles produce almost no greenhouse gas emissions (Madslien, 2002). Transit buses equipped with model year 2004 CNG engines produced 49% lower nitrogen oxides than those equipped with model year 2004 diesel engines ("Natural Gas Vehicles", 2011). In a study of CNG and diesel United Parcel Service (UPS) delivery trucks, CNG trucks produced 75% lower carbon monoxide emissions and 95% lower particulate matter emissions than diesel trucks of similar age ("Natural Gas Vehicles", 2011).

Another benefit to NGV is the predicted reduction of dependence on foreign oil. Feldstein (2003) writes that the United States imports nearly 60% of the oil Americans consume. This dependence on foreign supplies makes a country vulnerable to disruptions in world oil markets and fluctuations in world oil prices. Unlike oil, however, natural gas is still abundant. The Natural Gas Supply Association recently concluded that reserves show at least a 60-year domestic supply. In contrast, it is predicted that oil reserves are expected to run out between the years 2040 and 2075 (Lin, et al, 2008). In addition, only 56% of crude oil for U.S. refineries comes from North America; in contrast, 98% of natural gas comes from the U.S. (Woodyard, 2007). Not only does US consume a majority of the natural gas locally, but the new discovery of natural gas in Marcellus Shale is the largest source of domestic natural gas yet discovered in the US ("Marcellus Shale"). Thus, though natural gas is non-renewable, it is still widely available in the U.S. relative to oil. If CNG were more readily available for vehicle use, America's dependence on foreign oil would be greatly reduced, affording more time for the development of backstop technologies.

Given the real and potential benefits of using natural gas fuel instead of petroleum-based fuel, it is important to understand the fuel's demand. Given a demand function, we evaluate policy scenarios concerning recent breakthroughs in horizontal drilling that could make it possible to extract natural gas from the (largely untapped) reserves in the Marcellus Shale, a unit of sedimentary rock extending some 600 miles across eastern North America ("Marcellus Shale", 2013). In horizontal drilling, the "horizontal well" is first drilled down vertically to a depth above the target gas-bearing rock formation. Then special tools are used to curve the well so that the hole is drilled horizontally. This horizontal drilling has maximum contact with the gas-bearing rock formation, so that more gas can be produced from a single well ("Marcellus Shale", 2013).

Since the firms analyzed in this paper are price takers, we are primarily concerned with the retail price of CNG. However, with the increase in the supply of natural gas extracted through horizontal drilling, the retail price of CNG can both fall and rise, depending on how much of the extra supply is exported. One policy implication is that an increase in the supply of CNG, would lower CNG retail prices and thus decrease costs for these firms. There is evidence to suggest that this is in fact the case. Recent developments in extracting CNG, such as hydraulic fracturing, have significantly pushed the retail price of CNG down and are projected to continue to do so. According to Malik (2012) natural gas prices could hit a low of $2 per million BTU. This is a fall from the current $3.21 per million BTU (Malik, 2012), a decrease of almost 40%. These are wholesale prices, but a decrease in the wholesale prices would decrease the retail prices, and will decrease costs of firms that choose to use CNG over DF.

Another policy scenario is if the extra supply extracted of natural gas is exported around the world. Currently, there are at least 15 proposed terminal projects that have filed to export natural gas. The approval of these requests could precipitate a natural gas export of more than 25 billion cubic feet a day, equivalent to more than a third of domestically consumed natural gas. This increase in exports will drive up U.S. natural gas prices (Krauss, 2013). Thus we provide two policy scenarios: one in which these proposals to export are not met, and one in which they are.

### 2.2.2 Relevant Literature on Demand for Alternative Fuels

An alternative fuel vehicle (AFV) is defined as one that uses one of the following: liquified petroleum gas, CNG, liquefied natural gas, liquefied hydrogen, liquid fuel derived from coal, liquid hydrocarbons derived from biomass, or P-series fuels as defined by the Internal Revenue Service (IRS) ("Energy Policy Act of 1992", 1992). NGVs naturally fall under this heading, but little research has been done on them. In this paper, we intend to contribute to the current literature on AFVs by estimating the demand for NGVs; specifically, those that run on CNG.

One type of AFV that spawned much interest in recent years is the flexible-fuel vehicle. A flexible-fuel vehicle is a bi-fuel vehicle that can run on both ethanol and conventional gasoline. The flexible-fuel car that uses ethanol as an alternative fuel is a competitor to the NGV. The environmental benefits of using ethanol, however, are debatable. For example, Pimentel (2003) found that ethanol production actually *increases* environmental degradation, since the ethanol produced in the U.S. uses corn. Growing corn in the quantities needed to make ethanol a viable alternative fuel degrades the agricultural and natural environment and contributes to water pollution and air pollution. However, some noted benefits of ethanol are that gasoline enriched with ethanol contains more oxygen so that it burns cleaner[2]. The main advantage of ethanol is that it is renewable, whereas natural gas is not.

Natural gas fuel has also been studied, but to a lesser extent. Pascoli, et al (2001) find practical drawbacks to NGVs in Italy mainly due to a lack of an adequate refueling network, but also due to a lack of information about, and characteristics of, NGVs. In US, Krupnick (2011) when examining whether natural gas vehicles have a future in US, has concluded that NGVs have the potential to be “a good deal for society,”

We hope to address this situation by exploring characteristics of NGVs following the study of Anderson (2011), who maximizes the utility of households in Minnesota and estimates the preference for ethanol (E85) as a gasoline (E10) substitute. The households have an underlying distribution function for willingness to pay for E85. Conversely, in our paper we focus on CNG as a perfect substitute to diesel, where firms across the United States that use heavy duty vehicles minimize their costs, and in which the firms also possess a different underlying distribution function for the willingness to pay for CNG.

### 2.2.3 Objectives

We wish to understand the factor demand of CNG by a firm that minimizes its costs. This is the first paper to estimate the demand for CNG with the focus on commercial consumers that employ hybrid fleets, bi-fuel, or that can easily substitute between CNG and DF vehicles where the CNG run vehicles are either dedicated vehicles that only run on natural gas or dual fuel vehicles that need diesel for ignition assistance,(“Natural Gas Vehicles”, 2011). These vehicle technologies are already employed across the country by government agencies, transportation firms, and trucking corporations. Thus, the firm in this paper can be a

[2]cited from `http://e85.whipnet.net/e85.price/`

government agency or any other transport corporation that can substitute natural gas fuel for diesel fuel in its vehicles. This paper then looks at the price difference between diesel and CNG. This price difference is inherently dependent on preferences of choosing one fuel or the other by the firm, in order to minimize costs. The preferences can be decided based on environmental benefits, preferences of decreasing dependence on foreign oil, or lack of preference for one or the other. We estimate aggregate demand elasticity with respect to price differential compared to DF and find the demand to be relatively inelastic. Our aggregate model builds on structural preferences à la Anderson. That is, we estimate the distribution for marginal "indirect cost" differentials between CNG and DF. We also estimate the probability that the indirect costs of CNG for all the firms in 2009 exceeded those of diesel fuel (DF), in spite of the nascent supply infrastructure for CNG.

The demand for CNG is estimated across 50 states in the U.S., plus the District of Colombia, for the years 1989 to 2009. This estimation can further give an understanding of the market share of CNG relative to total fuel used by these respective firms given prices of diesel and natural gas fuel, as well as the preferences for the two different types. We also estimate how the number of stations affect the demand for CNG, since it is an important factor in determining indirect costs. We apply two-stage Least Squares (2SLS) to control for possible endogeneity in our estimation. Based on the results, we can calibrate the market shares. An increase in the price difference of DF over CNG does increase the demand for CNG. The number of stations also increases the demand, implying that the lack of stations is a possible barrier to an increase in the demand for CNG. Given the estimated factor demand for CNG, we then evaluate policy implications. To this end, we analyze the recent breakthroughs in extracting natural gas from the Marcellus Shale via horizontal drilling. We first analyze the implications of an increased supply of natural gas, and then we analyze the case in which that extra supply is exported across the world. We look into the equilibrium demand of these firms and whether it is increased or decreased under these two scenarios.

Section 1 describes the conceptual and simulation framework. Section 2 discusses the data and the estimation results. Section 3 discusses policy implications. Section 4 provides concluding remarks.

## 2.3 Modeling Framework

### 2.3.1 Firms' Optimization Problem

The choice between compressed natural gas (CNG) and diesel fuel (DF) as production inputs for transportation firms can be motivated via a cost minimization problem. We assume firms produce "miles" as their primary output, and that the fuel component of production costs is additively separable from other cost components, such as those related to drivers' wages, office personnel, and storage facilities. Also, we assume firms exhibit constant returns to scale, and that there are no technological constraints (i.e., these hybrid vehicles and natural gas vehicles are already employed by firms and government agencies.) Furthermore, we assume CNG and DF are perfect substitutes in the production of miles, given our focus on firms that use hybrid vehicles that can accommodate either fuel type at any refueling occasion. Later, we convert all data to gasoline-gallon equivalent (GGE) energy values, facilitating our one-to-one exchange between the two fuels.

The firm's optimization problem can then be stated as:

$$\begin{aligned} &\min_{n,g} p_n n + p_g g + \theta_n n + \theta_g g, \quad s.t. \\ &(n+g)\, mpg = m \\ &n, g \geq 0 \end{aligned} \tag{2.1}$$

where $n$ denotes the gasoline-equivalent amount of CNG, in gallons; $g$ denotes gallons of DF; $p_n$ is the price per gallon of gasoline-equivalent CNG; $p_g$ is the price of DF; "mpg" indicates "miles per gallon"; and $m$ is the targeted number of miles to be produced by the firm within a given time period (a full year in our case).

The $\theta$-terms in our cost function, $\theta_n$ and $\theta_g$, are non-price marginal cost components for each fuel type, analogous to Anderson's "direct utility benefit" terms in his model of households' choice between ethanol and conventional gasoline. These can have either sign, i.e. $\theta_{n,g} \in [-\infty, +\infty]$. For example, $\theta_n$ could capture "goodwill" gains amongst consumers from using domestically produced CNG. However, it could also incorporate extra transaction costs associated with finding CNG-dispensing gas stations. Similarly, $\theta_g$ could include loss of goodwill from increasing the market's dependence on foreign oil, or benefits such as special discounts with specific regular gasoline (RG) vendors. We will henceforth refer to these terms as "indirect costs".

The resulting Kuhn-Tucker conditions imply that the firm will use CNG given that the following condition holds: $\theta_n - \theta_g \leq p_g - p_n$, i.e. when the indirect cost of CNG over DF falls below the price differential between DF and CNG. If the opposite holds, the firm will use DF exclusively. The firm's optimal choice of fuel amount in either case is given as $n^* = g^* = \frac{m}{\text{mpg}}$.

### 2.3.2 Aggregation to State Level

One of the main advantages of Anderson's modeling framework is the preservation of a structural link between the decision maker's choice model and the aggregate econometric specification dictated by data availability. We largely follow his approach in our transition from the firm to the State level.

Assume there are $N_j$ firms in State $j$ that use a hybrid vehicle fleet. In the following discussion, we suppress the State-suffix $j$ for ease of exposition. CNG and diesel prices are assumed constant for a given time period $t$, and all firms are price takers. In contrast, each firm has its own, potentially time-varying, non-price marginal cost differential $\theta_{it} = \theta_{n,it} - \theta_{g,it}$. Thus, a given firm will use CNG exclusively in a given time period if $\theta_{it} \leq p_t = p_{g,t} - p_{n,t}$.

Furthermore, assume each firm receives all transportation orders at the beginning of a given time period. The desired miles to be produced in that time period, $m_{i,t}$, are calculated accordingly, and remain unchanged over the entire period. This is a realistic scenario for many primary consumers of CNG, such as school bus and waste disposal services, which operate on a regular schedule and cater to a fixed population of clients.

This immediately implies that a firm's fuel demand for period $t$ depends on fuel prices only to the extent of making the decision at the *extensive margin* as to which fuel to use for period $t$; that is, it depends only on the relative magnitude of $\theta_{it}$ to $p_t$. Following Anderson (2011), we assume that firm $i's$ fuel demand in period $t$, $q_{it}$, is jointly distributed with non-price preferences $\theta_{it}$ for the total population of hybrid-fleet firms in a given state with smooth, continuous, time-invariant pdf $f(q_{it}, \theta_{it})$. For example, the distributional link between fuel demand and indirect costs could arise as larger firms with higher fuel demand may have more opportunities to negotiate quantity discounts or capitalize on goodwill effects (e.g. via enhanced visibility of a larger fleet) than smaller enterprises.

The expected fuel demand over all firms with hybrid fleets in a given state, regardless of their choice of fuel *type*, is then given as

$$\begin{aligned} &E(q_{it}) = E_{\theta}(E(q_{it}|\theta_{it})) = \\ &\int_{\theta_{it}} \left( \int_{q_{it}} q_{it} f(q_{it}|\theta_{it})\, dq_{it} \right) f(\theta_{it})\ d\theta_{it} \end{aligned} \tag{2.2}$$

In contrast, the expected demand *conditional on having chosen CNG*, can be expressed as

$$\begin{aligned} &E\left(q_{it}|\theta_{it} \leq p_t\right) = \\ &\int_{-\infty}^{p_t} \left(\int_q q_{it} f\left(q_{it}|\theta_{it}\right) dq_{it}\right) f\left(\theta_{it}\right)\, d\theta_{it} = \\ &\int_{-\infty}^{p_t} E\left(q_{it}|\theta_{it}\right) f\left(\theta_{it}\right)\, d\theta_{it} \end{aligned} \tag{2.3}$$

Dividing and multiplying by the *unconditional* demand $E\left(q_{it}\right)$, and multiplying by the number of firms $N$ yields

$$\begin{aligned} &E\left(q_{it}|\theta_{it} \leq p_t\right) = \\ &NE\left(q_{it}\right) \int_{-\infty}^{p_t} \frac{E\left(q_{it}|\theta_{it}\right)}{E\left(q_{it}\right)} f\left(\theta_{it}\right)\, d\theta \end{aligned} \tag{2.4}$$

As explained in Anderson (2011), the ratio of expectations in the integrand can be interpreted as the fuel consumption by a "representative firm" with preferences $\theta_{it}$, *relative to* the fuel consumption of the typical firm, unconditional on $\theta_{it}$. Alternatively, this can be seen as the expected market share of a type $\theta_{it}$ firm relative to the prototypical firm. The function $h\left(\theta_{it}\right) = \frac{E(q_{it}|\theta_{it})}{E(q_{it})} f\left(\theta_{it}\right)$ can be interpreted as the *pdf* of the indirect cost premium for natural gas, where each firm is weighted by its relative fuel consumption. As noted in Anderson (2011), $h(\cdot)$ is a proper *pdf* that integrates to one. The *cdf* of this density, denoted $H\left(\theta_{it}\right)$ and given by the integral in the second line of (2.4), can be interpreted as the market share of natural gas relative to all fuel for the prototypical firm with a hybrid fleet. Logged aggregate demand for natural gas in period $t$ amongst all firms that use a hybrid fleet can then be written as

$$ln\left(Q_t\right) = ln\left(N\right) + ln\left(E\left(q_{it}\right)\right) + ln\left(H\left(\theta_{it}\right)\right) \tag{2.5}$$

Analogous to Anderson (2011), the logged market size (number of firms with a hybrid fleet) $\ln\left(N\right)$ will be absorbed by State and year-fixed effects in our empirical specification. The same holds for $E(q_{it})$. As noted in Anderson (2011), the latter implies that fuel demand is perfectly inelastic with respect to market prices during a given time period. This is perfectly consistent with our cost-minimization framework, which builds on the upfront assumption that firm operations are conditional on a fixed volume of customer orders in a given location and year (see above). Thus, $E(q_{it})$ is pre-determined for a given period, and in that sense "perfectly inelastic".

For the econometric implementation of this model we need a tractable specification on $H(\theta_{it})$. In Anderson (2011), $\theta_{it}$ can be interpreted as households' willingness-to-pay for ethanol as a gasoline substitute. It is thus plausible to bound this quantity from below by zero. This allows Anderson to use the exponential density (with an additional positive shifting parameter) to model its distribution. In our case, such a natural bound for $H(\theta_{it})$ does not exist: The indirect cost differential can theoretically fall on either side of the price differential $p_t$, including the negative realm. Given these considerations and the requirement of economic tractability, we instead employ a Laplace distribution for $\theta_{it}$ with unknown expectation $\mu$ and scale parameter $\gamma$; i.e.

$$h(\theta_{it}) = \frac{1}{2\gamma} exp\left(-\frac{|\theta_{it}-\mu|}{\gamma}\right) \tag{2.6}$$

Thus, the *pdf* is symmetric and kinked at $\mu$. The corresponding *cdf* is given by

$$\begin{aligned} H(\theta_{it}) &= \frac{1}{2} exp\left(-\frac{\mu-\theta_{it}}{\gamma}\right), \quad \theta_{it} < \mu \\ H(\theta_{it}) &= 1 - \frac{1}{2} exp\left(-\frac{\theta_{it}-\mu}{\gamma}\right), \quad \theta_{it} > \mu \end{aligned} \tag{2.7}$$

For identification purposes, we need to impose the additional assumption that $p_t < \mu$; i.e., that the price premium of DF over CNG falls below the *expected* indirect cost premium of CNG over DF. This appears plausible at least for our application, given the modest empirical range of $p_t$ of \$$1-2$ for most States and years in our data, and the likely negative sign of the indirect cost for DF (i.e. there are discount benefits large firms can enjoy at DF stations). Assuming that indirect CNG costs are likely positive (additional travel costs to reach CNG dispensing stations outweigh short-term goodwill gains), this increases the expected value for the indirect cost differential $\theta_{it}$.

Given this assumption only the first expression for $H(\theta_{it})$ in (2.7) applies. In logged form, this conveniently simplifies to

$$\begin{aligned} &\log\left(H\left(p_t\right)\right) = \log\left(\tfrac{1}{2}\right) - \left(\tfrac{1}{\gamma}\left(\mu - p_t\right)\right) = \\ &\left(\log\left(\tfrac{1}{2}\right) - \frac{\mu}{\gamma}\right) + \tfrac{1}{\gamma} p_t \end{aligned} \tag{2.8}$$

Thus, as in Anderson (2011), the inverse of the coefficient on the price premium can be interpreted as the scale parameter of the distribution of the cost premium $\theta_{it}$. The standard deviation can then be derived as $\sqrt{2\gamma^2}$. The term in parentheses will be absorbed by the State-fixed effects in our empirical specification. As illustrated in Anderson (2011) and shown below in detail, the expectation of the indirect cost differential ($\mu$) can be recovered via calibration. This, in turn, allows for an estimate of the proportion of firm-years for which $\theta_{it}$ exceeds zero, i.e. the probability over our entire research horizon that indirect costs for CNG exceed those for DF.

### 2.3.3 Econometric Specification

Our conceptual framework leads to the following estimable demand function for CNG amongst firms that operate hybrid vehicles:

$$y_{nt} = \alpha_n + \beta(-p_{nt}) + \mathbf{x}'_{nt}\boldsymbol{\delta} + \epsilon_{nt}, \quad \epsilon \sim n\left(0, \sigma^2\right) \tag{2.9}$$

The dependent variable is the logged aggregate CNG consumption in State $n$ and year $t$, which corresponds to $Q_t$ in (2.5) with the added State indicator $n$. State-level fixed effect $\alpha_n$ captures the first two terms in (2.5), the term in parentheses in the second line of (2.8), as well as other time-invariant unobserved effects at the state level that may drive CNG consumption (e.g., political leanings that sway the public towards reducing emissions or reducing the dependence on foreign oil).

Our econometric specification is completed by adding observed demand shifters $\mathbf{x}_{nt}$ with corresponding coefficient vector $\boldsymbol{\delta}$, and an idiosyncratic error term $\epsilon$ with the standard distributional assumption of normality with mean zero and variance $\sigma^2$.

## 2.4 Estimation

### 2.4.1 Data

The data we collected for this study is for commercial use vehicles only, across 51 states (including the District of Columbia) from the years 1989 to 2009. Public use vehicles are specified as: public transit buses, UPS trucks, Waste Management trucks, and other trucks and buses in which firms can decide whether to use CNG or DF. Some of these firms have hybrid fleets, in which a vehicle can easily switch from DF to CNG based on price and non-price preferences, while other firms have only NGVs or only Diesel-fueled vehicles, but can easily switch from using one type for another. The data for vehicle fuel consumption of natural gas, the amount of diesel consumed, wholesale and retail data for both CNG and DF come from the Energy Information Administration (EIA) ("EIA ", 2011). The number of stations per state, and the number of natural gas vehicles per state, come from the same

EIA website[3].

The retail price data for both CNG and DF in this dataset is not available for all states. In particular, there is no retail price data for Alaska, Maine, Vermont, or Hawaii. The data does, however, include the District of Colombia as its own separate region. Price data covers the years 1989 to 2009. Consumption data is available for years 1989 to 2009 for CNG and DF. The number of vehicles that use CNG starts from 1997 to 2009 and the number of stations that sell CNG in each state starts from the year 1992 to 2009. This compilation of data therefore leads to a somewhat unbalanced panel data set.

With 4 states missing, there are a total of 987 observations from 47 regions over 21 years. However number of stations is available only from 1992 onward. Hence the total number of observations is 744.

The data available is mostly for public vehicles, except for four states that start incorporating private vehicles. California starts using private vehicles in 1998, followed by Colorado in 1999, then New York in 2006, and lastly Utah in 2009. To study only public use vehicles, these observations for these states and respective years are excluded from the data set.

The vehicle consumption data is in millions of cubic feet, and the vehicle fuel price is (originally) in dollars per thousand cubic feet. Natural gas is measured in cubic feet but can then be converted to gasoline-gallon equivalent (GGE). In the summary table, Table 2.1, we have converted everything to GGE, that is all prices, and amount consumed by CNG[4]. The same

[3]The data can be found under "Renewable and Alternative Fuels", under "Analysis & Projections", `http://www.eia.gov/renewable/alternative_transport_vehicles/index.cfm`

[4]We convert the thousand cubic feet into BTUs and then convert the BTUs into GGE. A thousand cubic feet of gas is equal to 1.027 million BTU `http://www.physics.uci.edu/~silverma/units.html`. There are 114,118 BTU per GGE, `http://www.cleanvehicle.org/technology/TechBul7.pdf`

was done with diesel[5]. We deflated all prices to 2011, and converted \$/thousand cubic feet to \$/GGE, as well as \$/diesel fuel gallons to \$/GGE.

In Table 2.1, the consumption data for both diesel fuel and CNG is in million GGE. The retail and wholesale prices for both fuels is in \$/GGE. As can be seen from the table, the mean, min, and max for the DF retail prices are always larger than that of the CNG retail and wholesale prices. Also it is easy to notice that consumption, retail, and wholesale prices for the two fuels increase over time.

[5] 1 gallon diesel = 139,200 BTU `http://www.generatorjoe.net/html/energy.html`

| | States | CNG consumption (million gallons) | | | CNG price ($/gallon) | | | DF consumption (million gallons) | | | DF price ($/gallon) | | | CNG | Hybrid | CNG wholesale price ($/gallon) | | | DF wholesale price ($/gallon) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Included | mean | min | max | mean | min | max | mean | min | max | mean | min | max | Stations | Vehicles (000s) | mean | min | max | mean | min | max |
| 1989 | 47 | 0.00 | 0.00 | 0.04 | 0.77 | 0.60 | 0.93 | 604.06 | 9.20 | 3717.78 | 2.10 | 1.89 | 2.55 | 0 | 0 | 0.85 | 0.43 | 1.28 | 1.62 | 1.46 | 1.79 |
| 1990 | 47 | 0.05 | 0.00 | 0.66 | 0.82 | 0.15 | 1.43 | 536.14 | 12.85 | 3452.68 | 2.34 | 2.23 | 2.88 | 0 | 0 | 0.81 | 0.40 | 1.22 | 1.84 | 1.63 | 2.10 |
| 1991 | 47 | 0.07 | 0.00 | 0.60 | 0.83 | 0.43 | 1.15 | 306.45 | 0.02 | 3643.28 | 2.15 | 2.01 | 2.63 | 0 | 0 | 0.75 | 0.35 | 1.12 | 1.66 | 1.49 | 1.96 |
| 1992 | 47 | 0.10 | 0.00 | 0.85 | 0.86 | 0.19 | 2.42 | 606.67 | 38.47 | 3499.62 | 2.05 | 1.85 | 2.41 | 349 | 0 | 0.75 | 0.37 | 1.15 | 1.58 | 1.39 | 1.87 |
| 1993 | 47 | 0.18 | 0.00 | 2.29 | 0.87 | 0.49 | 1.69 | 639.40 | 6.35 | 3069.36 | 2.00 | 1.79 | 2.38 | 496 | 0 | 0.77 | 0.43 | 1.21 | 1.53 | 1.32 | 1.80 |
| 1994 | 47 | 0.35 | 0.00 | 4.95 | 0.76 | 0.35 | 1.42 | 706.65 | 6.46 | 3327.01 | 1.94 | 1.74 | 2.37 | 1041 | 0 | 0.75 | 0.39 | 1.21 | 1.47 | 1.25 | 1.75 |
| 1995 | 47 | 0.52 | 0.00 | 7.61 | 0.69 | 0.27 | 1.30 | 816.27 | 9.96 | 3442.97 | 1.87 | 1.71 | 2.25 | 1064 | 0 | 0.67 | 0.33 | 1.14 | 1.43 | 1.21 | 1.65 |
| 1996 | 47 | 0.56 | 0.00 | 11.38 | 0.67 | 0.27 | 1.25 | 794.99 | 17.05 | 3676.61 | 2.02 | 1.82 | 2.44 | 1489 | 60776 | 0.73 | 0.44 | 1.31 | 1.57 | 1.39 | 1.79 |
| 1997 | 47 | 1.32 | 0.00 | 12.12 | 0.73 | 0.40 | 1.20 | 791.08 | 11.97 | 3722.89 | 1.91 | 1.70 | 2.34 | 1495 | 71638 | 0.75 | 0.44 | 1.27 | 1.49 | 1.33 | 1.72 |
| 1998 | 47 | 1.52 | 0.01 | 13.23 | 0.68 | 0.03 | 1.29 | 933.73 | 8.87 | 3945.18 | 1.66 | 1.45 | 2.20 | 1105 | 65082 | 0.70 | 0.37 | 1.20 | 1.27 | 1.11 | 1.58 |
| 1999 | 47 | 1.87 | 0.00 | 16.57 | 0.71 | 0.28 | 1.21 | 929.86 | 6.10 | 4347.19 | 1.75 | 1.55 | 2.17 | 1048 | 70372 | 0.68 | 0.40 | 1.17 | 1.35 | 1.14 | 1.64 |
| 2000 | 47 | 2.07 | 0.01 | 18.20 | 0.83 | 0.25 | 1.34 | 1017.95 | 6.94 | 4513.59 | 2.24 | 2.07 | 2.72 | 1000 | 79215 | 0.86 | 0.61 | 1.44 | 1.80 | 1.63 | 2.14 |
| 2001 | 47 | 2.83 | 0.01 | 24.42 | 1.10 | 0.62 | 2.26 | 997.88 | 9.31 | 4786.87 | 2.04 | 1.75 | 2.29 | 995 | 95380 | 1.03 | 0.65 | 1.69 | 1.63 | 1.46 | 1.91 |
| 2002 | 47 | 2.86 | 0.01 | 25.18 | 0.85 | 0.50 | 1.43 | 986.49 | 5.55 | 4820.37 | 1.88 | 1.64 | 2.11 | 973 | 95380 | 0.82 | 0.51 | 1.44 | 1.50 | 1.37 | 1.75 |
| 2003 | 47 | 3.50 | 0.01 | 30.77 | 1.08 | 0.50 | 1.88 | 1030.35 | 10.33 | 4993.38 | 2.11 | 1.88 | 2.42 | 832 | 87220 | 1.00 | 0.73 | 1.72 | 1.70 | 1.56 | 1.97 |
| 2004 | 47 | 3.92 | 0.01 | 34.55 | 1.17 | 0.43 | 2.15 | 1045.28 | 8.21 | 4898.59 | 2.47 | 2.37 | 3.05 | 719 | 87040 | 1.10 | 0.81 | 1.79 | 2.02 | 1.84 | 2.40 |
| 2005 | 47 | 4.37 | 0.00 | 84.69 | 1.38 | 0.23 | 2.70 | 1100.44 | 4.75 | 5339.18 | 3.16 | 3.15 | 3.70 | 594 | 85618 | 1.32 | 1.04 | 1.80 | 2.63 | 2.34 | 2.93 |
| 2006 | 47 | 4.64 | 0.00 | 89.00 | 1.51 | 0.71 | 3.03 | 1095.64 | 12.15 | 5893.00 | 3.42 | 3.39 | 3.96 | 500 | 72964 | 1.28 | 0.87 | 1.88 | 2.87 | 2.61 | 3.16 |
| 2007 | 47 | 4.71 | 0.00 | 99.13 | 1.38 | 0.76 | 2.88 | 1537.41 | 18.22 | 7920.53 | 3.54 | 3.48 | 4.05 | 487 | 70376 | 1.17 | 0.82 | 1.70 | 3.00 | 2.77 | 3.24 |
| 2008 | 47 | 4.97 | 0.00 | 105.34 | 1.65 | 0.82 | 3.35 | 1437.21 | 26.64 | 7823.66 | 4.51 | 4.59 | 5.20 | 490 | 67694 | 1.28 | 0.85 | 1.69 | 3.81 | 3.55 | 4.10 |
| 2009 | 47 | 5.33 | 0.00 | 115.21 | 1.26 | 0.48 | 2.44 | 1316.37 | 20.24 | 7201.31 | 2.91 | 2.86 | 3.46 | 413 | 64750 | 0.97 | 0.54 | 1.49 | 2.46 | 2.32 | 2.74 |

Table 2.1: Descriptive statistics by year

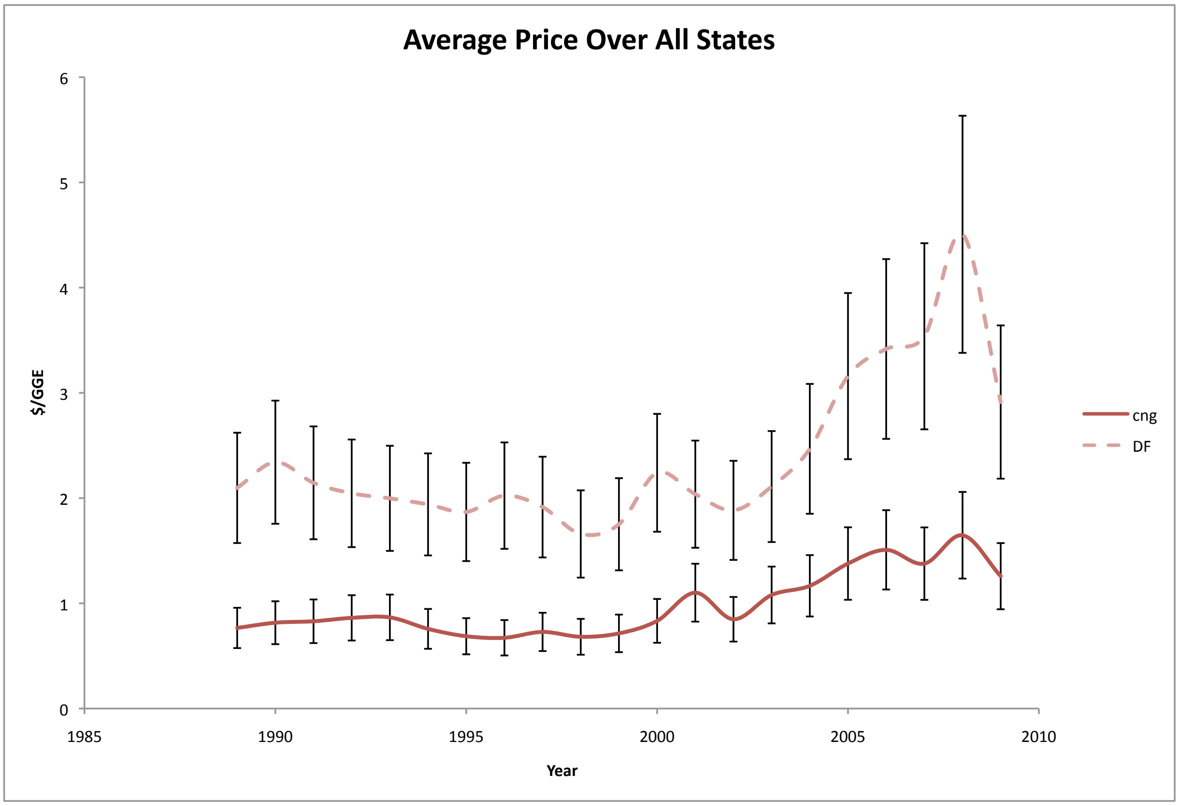



Figure 2.1: Natural gas fuel price vs. diesel price over the years 1989-2009

Figure 2.1 represents the time series graph, for prices for CNG and DF (averaged over states) for each year of our research periods with bounds for 1st and 3rd quartiles. The variability in CNG prices is generally lower than for DF prices. Also, both price trends are increasing over time, with DF prices being consistently higher. The price trends are almost parallel, implying that they are affected by similar exogenous factors. This serves as further evidence that DF and CNG are perfect substitutes in the market for fuel for public use vehicles.

The 2006-2008 crude oil prices peaked at US $133/barrel, (Baffes, Haniotis, 2010). This explains the large spike in Figure 2.1 for the year 2008. However, we can also note from this figure that CNG was severely less affected, thus showing less price volatility. This provides further evidence of CNG being an attractive alternative fuel.

### 2.4.2 Estimation Results

We run the econometric model via fixed effects and two-stage least squares (2SLS) in case there is endogeneity of the price term $p_t$, that is, un-modeled shifts in demand correlate with fuel prices. As assumed in Anderson, endogeneity bias in $p_t$ is possibly a secondary concern, since (i) any unobservables that affect both price and demand in a given time period and for a given state are likely to affect *both* price terms equally, such that the difference (that is, $p_t$) remains unchanged, and (ii) time-invariant confounders are captured by the state FEs.

However, we do instrument for $p_t$ along the lines of Anderson. That is, we use *supply-side* factors that are arguably uncorrelated with unobserved drivers of demand, similar as to Anderson. Thus we need to satisfy two assumption when picking our instruments: the "instrument relevant" assumption requires that the instruments given by vector $Z_{it}$ be correlated with the CNG premium, conditional on the controls: $E[P_n - P_g | Z_{it}, X_{it}, \varepsilon] \neq 0$ and the exclusion restriction, that the instruments be uncorrelated with demand, conditional on controls: $E[u_{it} | Z_{it}, X_{it}, \varepsilon] = 0$. Thus in our case we instrument wholesale CNG prices and wholesale DF prices for the retail price premium of CNG over DF. That is, we instrument the price premium of wholesale price of CNG over DF ($Z_{it} = P_n^w - P_g^w$), where $w$ serves as the wholesale price, for the retail price premium of CNG over DF. More precisely, the wholesale price premium serves as a supply-side factor, where the wholesale price premium is correlated with the retail price premium, but not correlated with the aggregate demand for CNG by these firms. Table 2.2 provides the results.

Table 2.2: Econometric results

| **Variable** | **FE** | **FE (2SLS)** |
|---|---|---|
| constant | 11.172**** | 10.663**** |
| | (.364) | (.321) |
| log(*stations*) | 0.604**** | 0.656**** |
| | (.111) | (.100) |
| $P_d - P_n$ | 0.316**** | 0.559**** |
| | (.085) | (.102) |
| N | 744 | 744 |
| $R^2$ | .521 | .513 |

Significance at the (*) 20%, (**) 10%, (***) 5%, (****) 1%

The F-statistic in the first stage of the 2SLS estimation is high, $F(2, 614) = 623.34$ thus indicating strong instruments. The price premium under 2SLS is significant and different from the FE estimator. This is different from Anderson's case in which he found only a 20% bias towards zero, while in our case there is 60% bias towards zero. Hence, there is a case of possible endogeneity which in our case can be corrected for by using the 2SLS estimates. We use the Hausman test, and find a Hausman statistic of 23, thus we use the 2SLS results, as they are consistent. Also, as the price difference increases, the amount of CNG demanded by firms to power their vehicles increases by .559. In other words, as the price of diesel goes up by $0.10, the factor demand for CNG goes up by 5.59%; and, as the price of CNG goes down by a $0.10, the factor demand for CNG goes up by 5.59%.

The coefficient on the number of stations is also significant and positive, indicating that as the number of stations increases, the amount of CNG demanded also increases. We can therefore think of the number of stations as infrastructure, and an increase in the infrastructure for

CNG increases the amount of quantity demanded by firms. While we have the number of vehicles that use CNG available, we choose to exclude it as a demand shifter in our model. The reason is that in our data the number of hybrid vehicles is highly correlated with the number CNG stations, a correlation coefficient of .725. Thus we cannot have both as demand shifters in our model.

### 2.4.3 Indirect Costs

Since our results only provide us with the scale parameter, $\gamma = 1/\beta$, we can "trick-out" the $\mu$ parameter in a fashion similar to that of Anderson. We first solve for the *empirical* market share, $H(\theta)$[6], and since we know all other components, we can calculate $\mu$ (the *expected* indirect price premium of DF over CNG). In our case, $\mu$ is a vector containing 21 elements, one $\mu$ for each year. However, since the number of vehicles documented for CNG use only starts from the year 1997, we are only able to attain 14 of the values. For a detailed explanation on how we found $\hat{\mu}$ see Appendix A. For the most recent year, 2009, $\hat{\mu} = 11.23$. For 2009, we can compute the expected proportion of firm-years for which $\theta_{it} > 0$; that is, the probability that the indirect costs of CNG exceeded those of DF is 0 .9987. Thus the indirect costs of CNG exceed those of DF significantly. This is most likely due to the lack of infrastructure, and low supply of natural gas available.

From the Laplace distribution we have that $\beta = 1/\gamma$, where $\gamma$ is the scale parameter. The

[6]The market share is equal to the total CNG divided by the total CNG and diesel that is used by firms with hybrid vehicles, or firms that can easily switch between the two fuels. The total is calculated as: average vehicle mile traveled (vmt)*number of vehicles/mpg, where the total number of vmt is found per year for buses and trucks, and the mpg=4.5, the average mpg between buses and trucks. `http://cta.ornl.gov/vtmarketreport/index.shtml`

standard deviation of the Laplace distribution is $\sqrt{2\gamma^2} = 2.527410$. Hence $\theta_{it}$ is in general positive, also implying that CNG indirect costs exceed those of DF majority of the time.

### 2.4.4 Elasticities

We discuss the elasticity of demand for these hybrid firms. An increase (decrease) in the price of DF (CNG) by \$0.10 will lead to an increase in the aggregate demand of CNG by 5.59%. To translate this into elasticities we have

$$\frac{\%\Delta Q}{\%\Delta P} = \frac{5.59\%}{\frac{.10}{P_n - P_d} * 100\%},$$

where $Q$ is the quantity demanded and $P$ is price. We take the mean over all years and states for our choice of $P_n - P_d$. In our data set, this is 1.55, so the elasticity of demand is .866, which is inelastic. Thus little price changes of the two fuels do not change the aggregate demand for CNG. However, if we pick the largest difference between $P_n - P_d = 3.35$, the price elasticity of demand is 1.87, which is elastic, implying that small price changes does affect aggregate demand for CNG.

## 2.5 Policy Implications

We construct crude aggregate demand for CNG for California, the largest consumer of CNG for NGVs, for 2009, the most recent year in our study.

Following Anderson, we derive the demand function using our 2SLS fixed effects results. We calibrate the demand by conditions $\hat{\mu}$, and $\hat{\gamma}$ derived above, with several different levels of $p_t$.

We compute the total CNG for California in 2009 using the properties of a log normal density as follows:

$$\hat{Q}_t = \exp\left(\hat{\ln Q_t} + \frac{1}{2}\sigma^2\right) \tag{2.10}$$

For details on how we compute $\hat{\ln Q_t}$, see Appendix B. Given the recent technological improvements in extracting natural gas from Marcellus Shale and the concomitant swell in the supply of natural gas, we study two scenarios. In the first scenario, we look at what happens to firm costs when the retail price of CNG falls due to increases in the supply of natural gas as stated by Malik (2012), where wholesale price of natural gas falls to $3.20/thousand BTU. In the second scenario, we look at what happens if the current 15 proposals to start exporting natural gas (due to the increase in supply) are granted (Krauss, 2013), and the wholesale price is raised to $6/thousand cubic feet (Krauss, 2013). Since these prices reported by these two sources are wholesale and in different units, we need to first convert them and then examine the retail prices. Thus we first convert all wholesale prices to $/GGE and estimate the retail premium prices using the first stage estimation from our 2SLS. The coefficient on the wholesale price premium is 0.815 and is statistically significant at the 1%. Using this result we can estimate the retail price premium for the two prices of interest, one before exports are considered, and one where exports are considered.

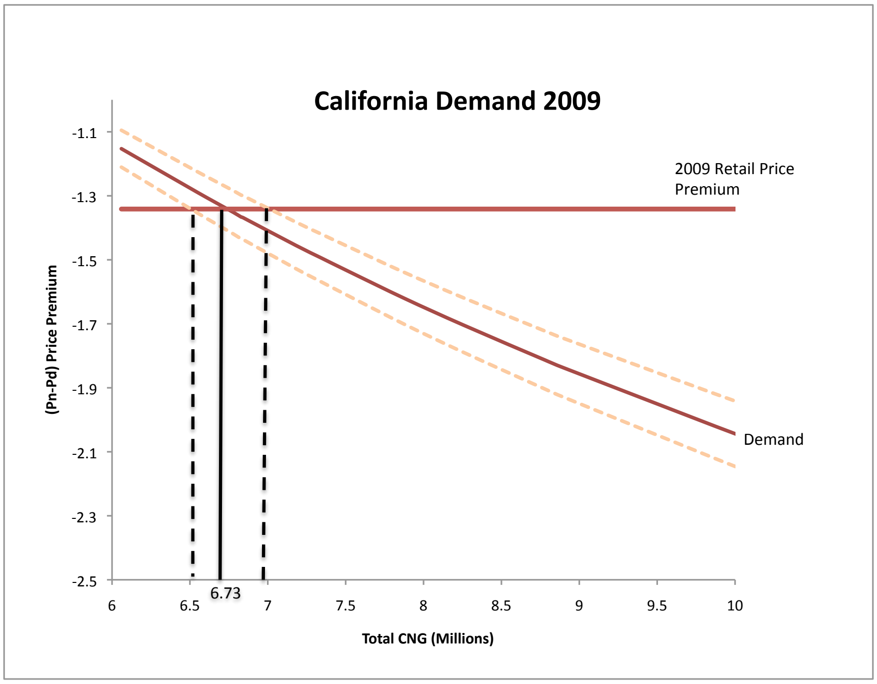
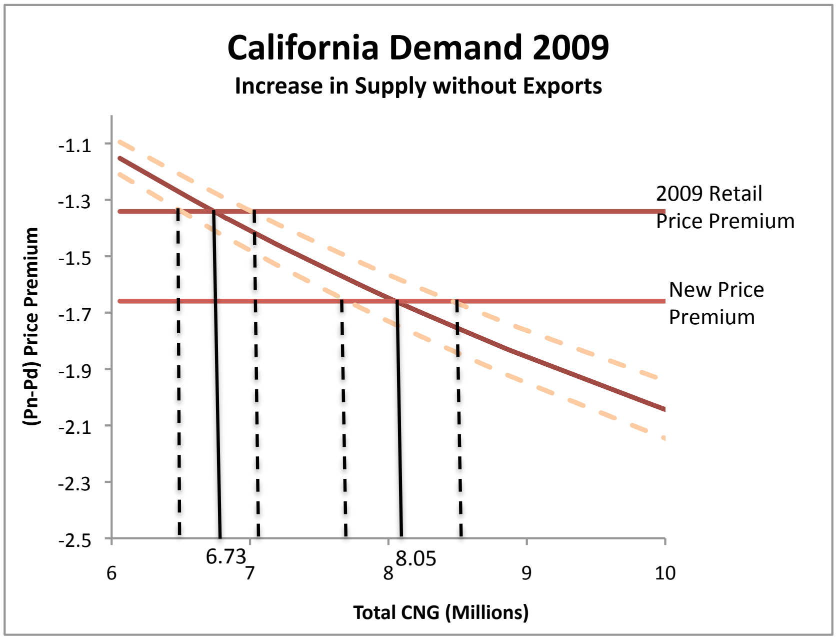
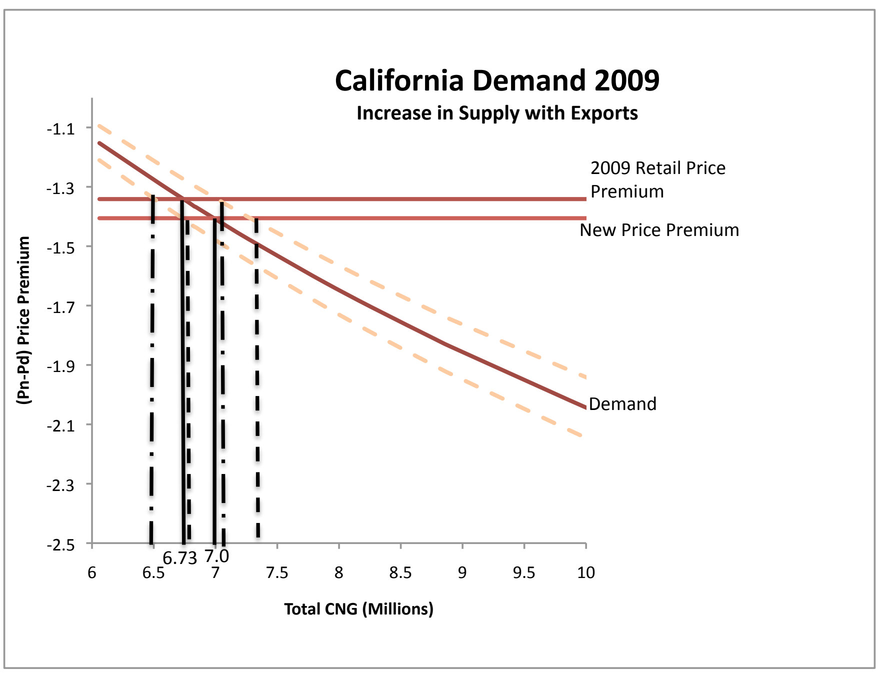



Figure 2.2: CNG aggregate demand and retail price premium of CNG over DF for 2009

Figure 2.2 shows the derived aggregate demand for California in 2009 alongside the retail prices of both CNG and DF in 2009, along with confidence bounds at 5%. The equilibrium demand in 2009 for California firms with hybrid fleets is 6.73 million CNG in GGE, with confidence bounds at 6.55 and 6.84 million GGE of CNG.




(a) Increase in supply of natural gas *without* exports




(b) Increase in supply of natural gas *with* exports

Figure 2.3: CNG aggregate demand and retail price premium of CNG over DF for 2009 for two different scenarios

In Figure 2.3, we use the prognosis of Malik (2012) that an increase in the supply of natural gas via horizontal drilling to reach Marcellus Shale will reduce wholesale prices for natural gas and thereby reduce retail prices for CNG. This in turn will push the “New Price Premium” in Figure 2.3a down, increasing equilibrium total CNG consumption from 6.73 million GGE to 8.05 million GGE, a 20% increase, with confidence bounds of 7.52 and 8.26. These hybrid firms benefit with the decrease in price by minimizing their costs significantly. Conversely, if proposals to start exporting natural gas are approved, domestic prices for natural gas would be driven up (Krauss, 2013). Therefore the “New Price Premium” in Figure 2.3b is pushed up, however still increasing the optimal equilibrium consumption of total CNG to 7.0 million GGE, a 4% increase with confidence bounds of 6.69 and 7.34. Thus this new technological advancement of horizontal drilling, as well as the discovery of natural gas in the Marcellus shale, has a very positive outcome on these firms that choose to substitute away from diesel, a petroleum fuel, to an alternative fuel, CNG by increasing the equilibrium total CNG consumption with a decrease in the price of CNG, and thus lowering their costs. This once again provides evidence towards CNG as an attractive alternative fuel.

As indicated in Figure 2.3, we make the simplifying assumption that supply stays perfectly elastic in the short term.

## 2.6 Conclusion

This paper estimates the demand for natural gas as an alternative fuel for diesel with an underlying distribution function that describes the willingness to pay for CNG by firms. We used EIA data and have found that an increase in the price of diesel by $.10, or a decrease in the price of natural gas by $.10, will increase the consumption by firms for CNG by 5.59%. That is, for an average price premium of $1.55, a 10% increase (decrease) in DF (CNG) is a

8.67% increase in aggregate demand for CNG. We were also able to find that an increase in CNG infrastructure – in particular, CNG stations – will increase demand.

Using our regression results, we were able to construct the market share of CNG, and calibrate the $\mu$s. For the available data, $\mu > 0$ for each year, indicating that the indirect costs for CNG exceed those of DF almost all the time. We were also able to determine the probability that the indirect costs of using CNG exceeded those of using DF for firms in 2009: .9987, almost all the time. This is a reasonable finding due to lack of existing infrastructure for CNG and lack of information about NGVs. Lastly, we were also able to use our regression findings to look into policy implications dealing with the new technology advancements in drilling for natural gas – in particular, horizontal drilling and its unique ability to tap the vast natural gas resources in Marcellus Shale. We looked into two policy scenarios dealing with this new technological advancement. In the first scenario, the increase in supply reduced prices for CNG, increasing the equilibrium demand for total CNG of firms with hybrid fleets. In the second scenario, in which an increase in supply induced exportation, the prices of CNG were driven up, but the demand for total CNG of these firms was still driven up by the increase in supply. Thus, according to these policy analysis results, these firms will benefit most if the proposals to start exporting the extra supply do not get passed. The firms in this case will benefit, but the suppliers of CNG will not due to lower prices. However, suppliers of natural gas will benefit more if the proposals do get passed, because the price of CNG will go up. In this scenario, however, the firms will be hurt by the increase in the prices for CNG, but still be better off than before the increase in supply.

While we have shown considerable evidence for CNG as an attractive alternative fuel to petroleum fueled vehicles, there remain several possibilities for future research in this area. Analysis with a larger data set is one somewhat obvious option. Natural gas as an alternative source of fuel has only been used in the US for a very short time, and data has only been collected in the US since 1989, yearly, not monthly, affording limited room for analysis. Additionally, when considering what factors make CNG's non-price marginal cost higher than those of DF, it seems reasonable to conclude that an absence of CNG infrastructure and dearth of information about NGVs is at fault. But there might be other factors at play, and this is certainly worth looking into. Lastly, with an increased data set, looking into the increase in the number of firms that start to invest in these hybrid fleets as a measure of increased promise of the natural gas vehicle is another possibility.

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# CHAPTER 3

# ESSAY 2: WHAT EXPLAINS THE RTA 'TRADE EFFECT'? EVIDENCE FROM SPS AND TBT POLICIES

## 3.1 Abstract

A number of studies have found that regional trade agreements (RTAs) significantly increase members' trade flows. While recent studies have begun to explore the reasons for this, none have examined whether the RTA trade effect varies systematically with the number of policy areas covered by the agreement. While the empirical trade literature has shed considerable light on the impressive trade creating ability of RTAs (Grant & Lambert, 2008), much less is known about why these agreements appear to be so successful. In this study we draw on a new database from the World Trade Organization of trade policy areas covered by RTAs to examine whether the degree of trade liberalization is an important determinant of the RTA trade effect. An augmented, theoretically consistent gravity equation is developed to explore the effects of RTAs on trade conditional on the policy areas they include. In particular, we investigate two policy areas that are particularly important for agricultural trade, sanitary and phytosanitary measures (SPS) and technical barriers to trade (TBT). The results suggest that harmonization of non-tariff measures inside RTAs matters: agreements that liberalize

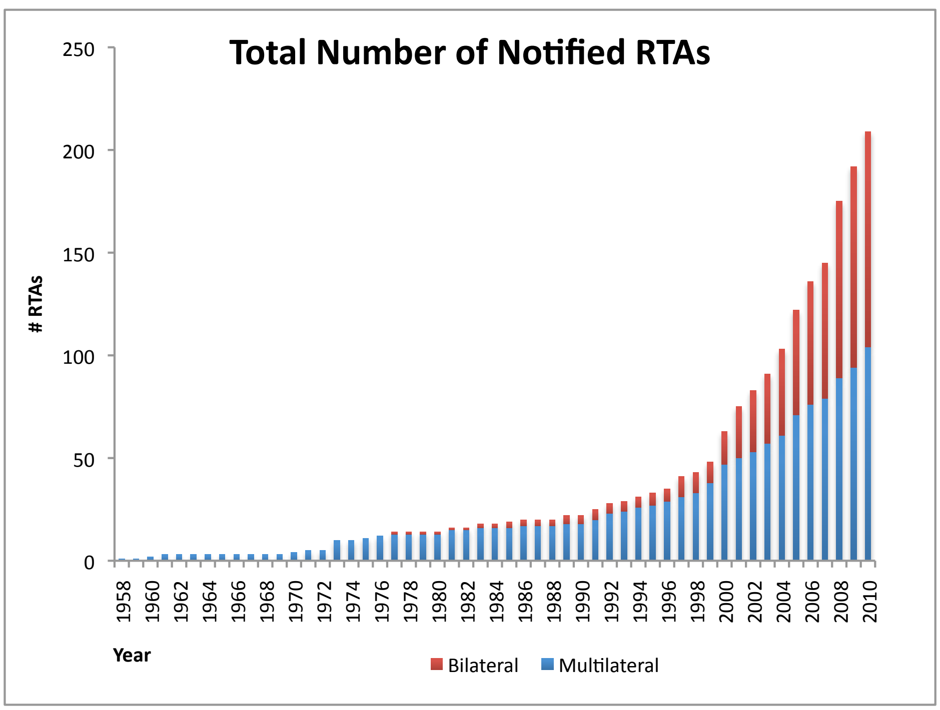
these policies increase members' agricultural trade by an additional 63 percent compared to agreements that do not. We conclude that studying the components of RTAs – in particular, the policy areas covered by these agreements – is important when analyzing the determinants of RTA trade effects.

## 3.2 Introduction

Regional trade agreements (RTAs) were first introduced into the gravity equation to measure the potential increase or decrease in members' bilateral trade flows relative to countries that do not participate in such agreements. The gravity model has performed very well in measuring the impact of RTAs on trade flows (Grant & Lambert, 2008). Indeed, Eichengreen & Irwin (1998) called the gravity model "the workhorse of empirical studies to the virtual exclusion of other approaches." While there have been a number of studies estimating the effects of RTAs on trade flows, none have considered the policy areas sometimes included in these RTAs as a possible explanation for why RTAs are successful in increasing trade flows. We use the gravity equation to explore the effects of RTAs on trade by focusing on the policy areas they include. We look in particular at two policy areas, sanitary and phytosanitary measures (SPS) and technical barriers to trade (TBT). We conclude that studying the components of RTAs – in particular, policy areas included in RTAs – is important when analyzing the successes or failures of RTAs in liberalizing trade.

RTAs have proliferated in part because they are easier to negotiate than multilateral negotiations under the purview of the World Trade Organization (WTO). Multilateral negotiations require consensus on trade liberalization commitments by over 150 members, whereas RTAs negotiations often proceed with only two or more contracting parties that share some common denomination; that is, a "region." As of January 2013, there were 546 notified RTAs, and of these, 354 are in force (WTO, 2011). Some prominent RTA negotiations include the United States - European Union (US-EU) agreement and the Trans-Pacific Partnership (TPP), a potential agreement involving nine countries (Australia, Brunei Darussalam, Chile, Malaysia, New Zealand, Peru, Singapore, Vietnam, and the US) that strive to enhance trade and investment among partner countries to promote innovation, economic growth, and creation and retention of jobs ("Office of the United States Trade Representative", 2011). Appendix C lists all the notified RTAs from 1958 to 2010 with agreements in bold denoting those for which we have additional information about trade policy areas liberalized within the agreement. Figure 3.1 divides the RTAs in our two datasets into two categories: *multilateral* (more than two contracting parties) and *bilateral* (exactly two contracting parties).

Figure 3.1: Number of RTAs




From Figure 3.1 we can tell that the number of RTAs in force – particularly bilateral RTAs – increase over time. This confirms the intuition that RTAs are much easier to negotiate when fewer parties are involved. This, coupled with the fact that RTAs have been shown to both increase trade flows and liberalize trade, helps to explain the rise in the number of RTAs since 2000.

While there has been meta-analysis examining effects of RTAs on trade flows (Cipollina & Salvatici, 2010), we outline some of the most salient findings across RTA literature in Table 3.1. All studies confirmed an increase in trade flows due to RTAs, but none studied the policy areas included in the RTAs as a possible reason for their success.

Table 3.1: Past literature on RTAs

| **Study** | **Year** | **What They did?** | **Result** | **Coef** (Significant at 1%) |
|---|---|---|---|---|
| Baier & Bergstrand | 2007 | Address endogeneity-include lagged terms and use bilateral pair and country-time fixed effects | Find an ATE of **.61** - five to six times larger than using OLS | 0.61 |
| Eicher, et al. | 2012 | Bayesian Model Averaging-include 13 RTAs | 8 out of 13 are trade creating | .66 - 1.48 |
| Furtan & van Melle | 2004 | Estmate the border effects for agricultural commodities for NAFTA | border effects have declined over 1992-1998 for NAFTA | .32-.43 |
| Ghosh & Yamarik | 2004 | Extreme bound analysis-examininign 12 RTAs | 8 out of 12 are trade creating | .0067-2.22 |
| Grant | 2012 | Dissected the economic integration into three categories: deep integration agreements, moderate integration agreements, and shallow integration agreements | Deep integration agreements are the ones responsible for the large increase in trade flows. | .27-1.44 |
| Grant & Lambert | 2008 | Dissect trade to agricultural trade and non-agricultural trade | RTAs where more successful in agricultural trade than non-agricultural trade | Total RTA effect: .25-1.61 |
| Santos & Tenreyro | 2006 | Correct for endogeneity caused by zero trade flow. Use Poisson maximum likelihood estimator (PPML) to estimate the gravity equation. | Once endogeneity is corrected for, FTA-a type of RTA still increases trade flows significantly. | .14-.38 |
| Vollrath, Hallahan & Gelhar | 2006 | Examined three RTAs: NAFTA, EU, and MERCOSUR- on food trade. | Found that NAFTA, MERCOSUR, and the EU increased food trade among member countries beyond what would have occurred in their absence. | 1.10-1.62 |
| Zahniser, et al. | 2002 | Examine agricultural trade in the Western Hemishphere, in particular RTA: NAFTA. | Trade between U.S. and Mexico after 1989 significantly increased. | .34-.48 |

Prior to the study by Baier & Bergstrand (2007), the effect of RTAs on trade showed conflicting evidence. Ghosh & Yamarik (2004) showed econometrically using extreme bound analysis that the reason for the fragility in the RTA effect was due to incorrect specification of the gravity model. They concluded that the cross-sectional gravity equation yielded highly unstable results, and once this is corrected, RTAs are found to increase trade. In one of the definitive studies of RTAs, Baier & Bergstrand (2007) showed econometrically that cross-sectional results are likely biased because of the endogeneity of countries' decision to select into RTAs. Using a set of Heckman control functions on cross-sectional data, the authors attempt to control for this endogeneity. However, the fragile nature of the RTA effect continued; in some years the trade increase of RTAs was implausibly large and statistically significant while in other years the RTA trade effect was negative and statistically significant. Baier & Bergstrand (2007) went on to show that panel data methods can correct many of the endogeneity concerns of RTAs. In particular, they show that if countries' decision to select into RTAs is because of policy-related barriers 'behind a nation's border' that are unobservable to the econometrician, and these unobserved policy barriers are slow moving (i.e., they do not change over time), then panel data with country-pair fixed effects can circumvent many of the endogeneity biases present in cross-sectional data. Revisiting the RTA trade effect using panel data and a theoretically consistent version of the gravity equation, the authors found that RTAs approximately doubled members' trade after ten years.

Panel data methods have also been applied to estimate the impact of RTAs on members' agricultural trade (Zahniser, et al. (2002); Furtan & van Melle (2004); Vollrath, Hallahan, & Gelhar (2006); Vollrath, Grant, & Hallahan (2012); Lambert & McKoy (2008); Koo, Kennedy & Skripnitchnko (2006); Sun & Reed (2010); Jayasingshe & Sarker (2008); Sarker & Jayasinghe (2007); Grant & Lambert (2008); and Grant (2013)). Grant & Lambert (2008) examined agricultural and non-agricultural trade effects of RTAs and found that RTAs increase members' trade in both sectors, although the impact in agriculture was economically and statistically larger compared to non-agricultural trade. The authors attribute this effect to the relatively large pre-existing trade distortions in agriculture prior to entry into force of RTAs. However, some recent studies have found that not *all* RTAs are successful in increasing members' trade. For instance, Grant (2013) found that the level of economic integration can actually have an effect on how successful an RTA is. Eicher, Henn & Papageorgiou (2012) looked at thirteen preferential trade agreements (PTAs) and found that only eight of them were trade-creating[1].

While the empirical literature investigating the trade flow effects of RTAs is vast, an important policy question remains: what factors are responsible for the impressive trade effects RTAs seem to generate? In this paper, we aim to provide answers to this important question by focusing on the level of trade liberalization ambition pursued by these agreements. First, we draw on a new database developed by the WTO's Committee on Regional Trade Agreements (CRTA), which is responsible for overseeing the implementation of RTAs, that identifies 14 policy areas that may be included in an RTA's schedule of trade liberalization commitments. Second, we construct two new datasets on agricultural and industrial product trade over the periods 1980-2008 and 1965 to 2010, respectively, and match the policy areas of 96 regional trade agreements to bilateral trade flows in each dataset and a number of other controls. Finally, we undertake a thorough empirical analysis using an augmented version of the theoretically consistent gravity equation to examine whether the RTA trade effect is an increasing function of the number of trade liberalization policy areas covered by the agreement.

For agricultural trade we focus specific attention on two policies, SPS and TBT, which were established during the Uruguay Round (UR) Agreement on Agriculture (AoA 1994) nego-

[1]PTAs are similar to RTAs but differ in that PTAs feature unilateral trade preferences, whereas RTAs are fully reciprocal

tiations to address the emerging debate over the use of standards and non-tariff measures in international trade. The UR Agreement on the Application SPS measures permits WTO members to take scientifically based measures to protect plant, animal, and human health from the introduction of pests and disease through international trade. The SPS agreement is designed to be scientifically based and not discriminatory between countries with similar conditions to prevent the disingenuous use of these measures as disguised protection. In case of particularly stringent measures, countries must present scientific justification and then a compromise that permits countries to take measures to protect public health within their borders so long as they do so in a manner that is minimally trade distorting. The WTO's Agreement on Technical Barriers to Trade strikes a balance between the policy goals of trade facilitation and national autonomy in technical regulation in three ways: the agreement encourages standard equivalence between countries, promotes the use of international standards, and mandates that countries establish enquiry points and national notification authorities. SPS and TBT disputes figure prominently in agri-food trade because of the sensitive nature of pest and disease risk in food consumption (Peterson et al, 2013). Thus, RTAs that go beyond the reduction or elimination of tariffs by restricting or harmonizing the use of non-tariff measures are likely to increase the transparency of border measures inside RTAs leading to a significant effect on members' trade.

We systematically dissect RTAs to determine which are successful and which are not. More precisely, we first estimate the impact of having any policy areas in an RTA and whether that increases trade flows in the agricultural and world trade data. We then focus on SPS, TBT, and another twelve policy areas mandated by the WTO that can be included in an RTA and estimate which policy areas have a significant impact on trade flows. Table 3.2 lists all of these policy areas considered in our analysis. The 14 policy areas covered under certain RTAs are also presented in the WTO (2012) report documenting the construction of these measures which are based on actual legal texts of each RTA notified to the WTO. These policy areas are classified under WTO+, which are policy areas that are subject to some of the commitments in WTO agreements; that is, they already fall under the WTO mandate.

Table 3.2: WTO+ policy areas

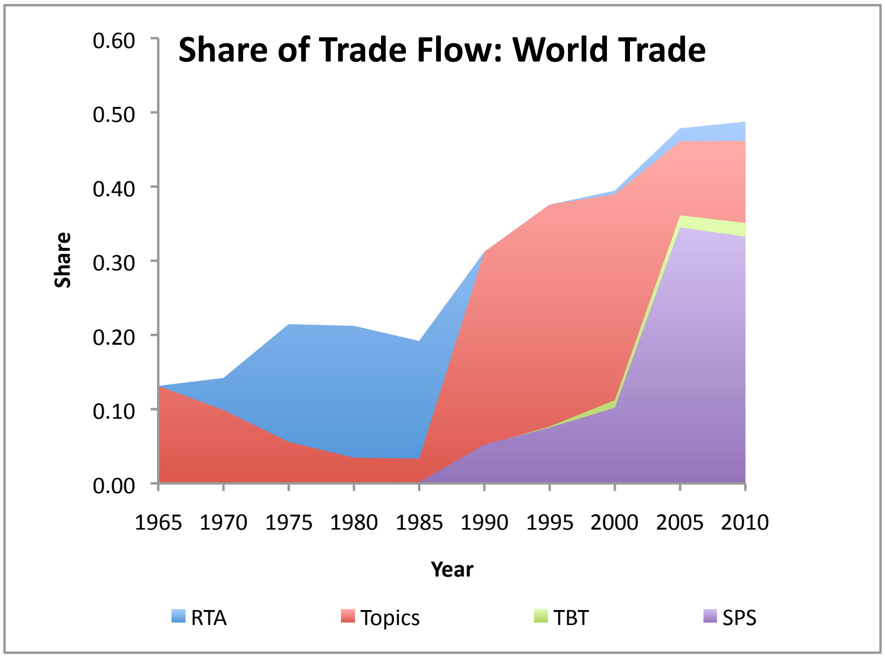
| **WTO + Areas** | |
|---|---|
| PTA industrial goods | Tariff liberalization on industrial goods; elimination of non-tariff measures |
| PTA agricultural goods | Tarriff liberalization on agricultural goods; elimination of non-tarriff measures |
| Customs administration | Provision of information; publication on the Internet of new laws and regulations; training |
| Export taxes | Elimination of export taxes |
| SPS measures | Affirmation of rights and obligations under the WTO Agreement on SPS; harmonization of SPS measures |
| State trading enterprises | Establishment of an independent competition authority; nondiscrimination regarding production and marketing condition; |
| Countervailing measures | Retention of Countervailing measures rights and obligations under the WTO Agreement (Art VI GATT) |
| Anti-dumping | Retention of Antidumping rights and obligations under the WTO Agreement (Art. VI GATT). |
| State aid | Assessment of anticompetitive behaviour; annual reporting on the value and distribution of state aid given |
| Public procurement | Progressive liberalisation; national treatment and/or non-discrimination principle; specification of public procurement regime |
| TRIMS measures | Provisions concerning requirements for local content and export performance of foreign direct investment (FDI) |
| GATS | Liberalisation of trade in services |
| TRIPS | Harmonisation of standards; enforcement; national treatment, most-favoured nation treatment |
| TBT | Affirmation of rights and obligations under the WTO Agreement on TBT; harmonization of TBT regulations |

The definitions can be found in Krishna (2012).

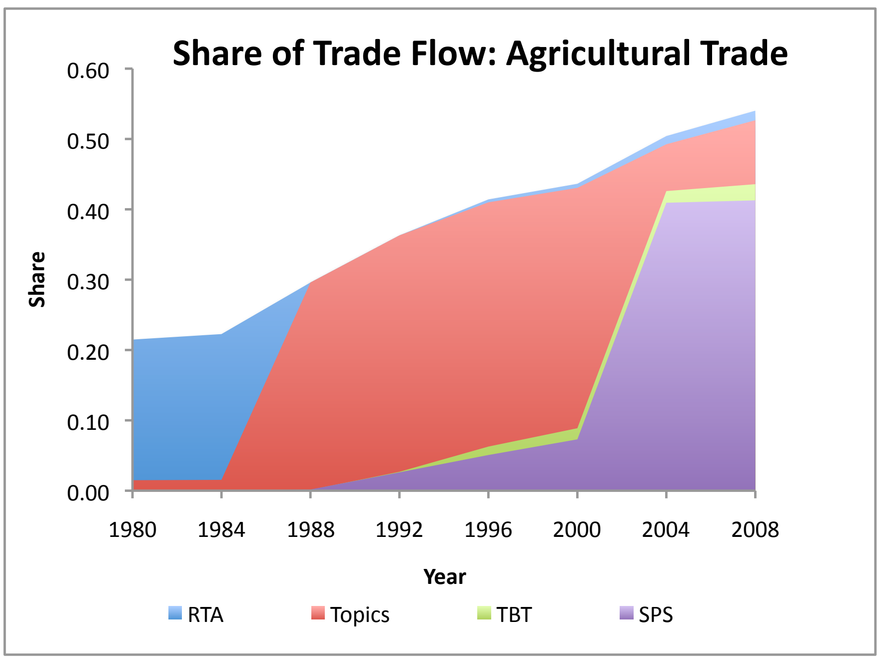
Hereafter, we refer to these policy areas as *topics*. Most topics are self-explanatory, with a few exceptions. "Countervailing measures" are enforced in cases when the exporter's products are subsidized, hurting domestic producers in the importing country. Similarly, "Antidumping" prevents an exporting country from shipping a product at a price below the cost of production or fair market value. "Public procurement" describes instances where the country has to procure goods and services on behalf of the public authority, or government. This is enforced to prevent fraud, waste, corruption and local protectionism. As explained earlier, "SPS measures" refer to sanitary and phytosanitary measures, which can include a number of trade restrictions such as requiring animals and animal products to come from disease-free zones; inspection of products for microbiological contaminants; mandating a specific fumigation treatment to control for pests in fruits and vegetables; and setting stringent maximum allowable limits on pesticide residues in food products ("Introduction to the SPS Agreement"). "TRIMS measures", or trade-related investment measures sets rules that apply equally to domestic and foreign investors. This makes it easier to operate in foreign markets. "GATS" stands for the General Agreement on Trade in Services such that not only does the RTA cover trade liberalization on goods but also services. "TRIPS" stands for Trade-Related Aspects of Intellectual Property Rights. It sets minimum standards for intellectual property rights. Lastly, "TBT" – technical barriers to trade – includes ensuring safely that regulations, standards, testing, and certification procedures do not create unnecessary obstacles, while providing members with the right to implement measures to achieve legitimate policy objectives such as protection of human health and safety of environment. We focus on SPS and TBT because SPS because deals with safety of food health and is therefore particularly relevant to agricultural trade. TBT, on the other hand, addresses differential product standards across countries (i.e., voltages, measurement, wattage, calories, etc.) for many traded products, not just agri-food products. While other topics are important to international trade, SPS and TBT measures feature prominently in agri-food trade.

Figure 3.2: Share of trade flows by category for the two data sets.

(a) World trade




(b) Agricultural trade



From Figure 3.2, we see that 50% of trade flows are done through an RTA by the last year of each dataset. Also, the amount of trade flow that includes policy areas (in particular, SPS and TBT) increases over the years.

We are not the first to focus on WTO+ areas. Krishna (2012) looked into anti-dumping policy areas and found that policy options for the WTO should be considered when estimating the effects of PTAs. Moreover, Fulponi et al (2011) examined SPS and TBT by looking at agricultural trade and the prevalence of SPS and TBT under South-South Latin American RTAs, finding the impact to be fairly modest. However, they found that under all WTO+ areas, SPS and TBT measures are the most promising non-tariff agreements that can liberalize agricultural trade. They did not, however, econometrically measure the magnitude of the impact of SPS and TBT on agricultural trade. We, on the other hand, are the first to look at more RTAs all over the globe for both world trade and agricultural trade and systematically analyze the importance of policy areas in RTAs, particularly SPS and TBT safety measures, and their quantitative effects on trade.

This paper is organized as follows. The conceptual model is explained in Section 2. A description of the datasets can be found in Section 3. Results are presented and discussed in Section 4, while Section 5 offers some concluding remarks.

## 3.3 Conceptual Model

To estimate whether the RTA trade effect can be explained by the trade liberalization policy topics they cover we develop a more flexible version of the gravity equation in international economics. The gravity equation was first introduced by Tinbergen (1962), who drew inspiration from Newton's Law of Universal Gravitation, which states that the force of gravitational attraction between objects $i$ and $j$ can be written in the form

$$F_{ij} = G\frac{M_i M_j}{D_{ij}^2}. \tag{3.1}$$

In the gravity model, $F_{ij}$ is the "flow" from origin $i$ to destination $j$ (alternatively, the monetary flow); $M_i$ and $M_j$ are the relevant economic sizes of the two locations (usually their gross domestic products (GDPs)); $D_{ij}$ is the distance between the locations; and $G$ is a gravitational constant, which in the empirical literature accounts for other known factors that promote or impeded trade.

Though plausible, the gravity model was not supported with sound economic reasoning until Anderson (1979) provided a derivation using the Constant Elasticity of Substitution (CES) expenditure function. Further improvements were made by Bergstrand (1985), who explored the theoretical determination of bilateral trade in a series of papers in which the gravity equation was cast in a monopolistic competition framework; Helpman (1987), who used a differentiated products framework with increasing returns to scale to justify the gravity model; and Deardorff (1998), who proved that the gravity equation characterizes many theoretical models of bilateral trade and can be justified from standard trade theories. The missing link in many of the theoretical foundations for the gravity equation was the role of multilateral prices. The latest contribution to the gravity model is the introduction of the multilateral resistance terms by Anderson & van Wincoop (2003). According to the authors, trade flows not only depend on bilateral trade costs, but also on bilateral trade costs relative to a measure of both countries' trade costs with all of their partners in the rest of the world.

We provide the derivation of the gravity equation as follows:

The model starts from the constant elasticity of substitution framework (Feenstra, 2004), where we maximize the utility for country $j$:

$$U_{jt} = \sum_{j=1}^{C} N_{it} C_{ijt}^{\frac{\sigma-1}{\sigma}} \tag{3.2}$$

- $U_{jt}$ is the utility of country $j$ in year $t$
- $N_{jt}$ is the number of product varieties shipped by country $i$
- $c_{ijt}$ is the consumption of any product sold by country $i$ and consumed in country $j$
- $\sigma$ is the elasticity of substitution between varieties

Subject to:

$$E_{jt} = \sum_{i=1}^{C} N_{ti} p_{it} t_{ijt} c_{ijt} \tag{3.3}$$

- $E_{jt}$ represents aggregate expenditure in country j
- $p_{it} t_{ijt} = p_{jt}$ is the price linkage equation that determines destination prices in importer $j$'s market ($p_{jt}$) inclusive of the exporter's origin price ($P_{it}$) and bilateral ad-valorem trade costs $t_{ijt}$

After maximizing the utility subject to the expenditure function we get the expression for the demand of each product:

$$c_{ijt} = E_{jt}(t_{ijt})^{-\sigma} \left( \frac{P_{it}}{P_{jt}^{-1/\sigma}} \right) \tag{3.4}$$

where $P_{jt}$ is the country $j$'s CES price index defined as:

$$P_{jt} = \left( \sum_{j=1}^{C} N_{it} (p_{it} t_{ijt})^{1-\sigma} \right)^{\frac{1}{(1-\sigma)}} \tag{3.5}$$

In the Dixit & Stiglitz (1997) and Krugman (1980) monopolistic competition framework, demand is symmetric for all varieties from country $i$, so we can multiply the quantity purchased ($c_{ijt}$) by the number of varieties available, $N_{it}$, and the price of each variety, ($p_{jt}$), to have an expression for total value of bilateral trade in year $t$ ($X_{ijt}$):

$$x_{ijt} = \mu_{it} E_{jt} (t_{ijt})^{1-\sigma} P_{jt}^{\sigma-1} \tag{3.6}$$

where $\mu_{it} = N_{it} P_{it}^{1-\sigma}$ is a competitive indicator of the exporter because it determines the number of product varieties and price of each good shipped. In this (partial equilibrium) framework, we seek to understand thetrade flow impacts of RTAs with differing levels of topics covered. The formation of an RTA affects the price index ($P_{jt}$) through the ad–valorem trade cost component ($t_{ijt}$).

$$t_{ijt} = \exp(-\rho RTA_{ijt}) z_{ijt} \tag{3.7}$$

where $\rho$ parameter and $RTA_{ijt}$ is a dummy variable taking on 1 if $i$ and $j$ belong to a regional trade agreement, 0 otherwise. Then $z_{ijt}$ is a residual component of all other trade costs that promote factors affecting bilateral trade. Lastly, $Y_{it}$ and $Y_{jt}$ are proxies for $\mu_{it}$ and $E_{jt}$ , GDPs of the respective countries, as the level of competitiveness and aggregate expenditure, respectively.

Thus, the basic gravity equation after taking logs on both sides in a panel framework is:

$$\ln(X_{ijt}) = \beta_0 + \beta_1 \ln GDP_{it} + \beta_2 \ln GDP_{jt} + \beta_4 RTA_{ijt} + \beta_3 \ln D_{ij} + \gamma Z_{ijt} + \epsilon_{ijt}, \tag{3.8}$$

where, $D_{ij}$ was originally part of the $Z$ vector, additional controls in the $Z$ vector include

$Contig_{ij}$ and $lang_{ij}$, taking on 1 if they are contiguous and share the same language, and 0 otherwise. If the two countries share a land border (are contiguous) and if 90 percent of the population speaks the same language, respectively. So if two countries are contiguous and speak the same language, it is more likely they would participate in trade since location and information symmetries increase international transactions. Grant & Lambert (2008) also use these two trade barriers when estimating the effects of RTAs on trade flows. However, while sharing a land border and speaking the same language are important variables to consider, there are a host of other factors that potentially promote or impede bilateral trade. As discussed below, we also consider a comprehensive set of bilateral pair fixed effects to absorb all time-invariant country-pair factors influencing trade.

According to Anderson & van Wincoop (2003), multilateral prices influence trade and should be added to the empirical specification so that the equation is well grounded in theory. That is, trade between countries $i$ and $j$ also depends on how costly it is for these countries to trade with the rest of the world. However, multilateral price data are notoriously difficult to measure, much less observe. Thus, a computationally easier method to control for multilateral resistance terms is to estimate (3.8) using exporter ($i$) and importer ($j$) fixed effects in the corss-section or time-varying importer and exporter specific fixed effects in a panel setting to obtain consistent estimates. (Anderson & van Wincoop, 2003; Feenstra, 2004). This is feasible in our estimation because an importer can import from more countries than it exports to, and the importer does not necessarily have to export to the same countries it imports from.

### 3.3.1 Introduction of Topics

We continue our study by looking at the individual topics that can be covered in an RTA. There are a number of reasons to predict that including topics in an RTA's trade liberalization commitments will increase trade. For example, some of our topics directly affect prices and therefore the terms of trade. Reduced export taxes, greater oversight on the implementation of SPS and TBT, agricultural tariffs, for example, will increase firms' willingness to export, all else equal. Other topics can affect trade, but only indirectly, through general equilibrium effects. For example, protecting trade-related intellectual property rights should provide incentives for firms to innovate and increase workers production.

To examine whether greater coverage of topics inside RTAs stimulates members' trade, we add four dummy variables to the vector $Z$ that control for (i) trade flow changes due to the formation of an RTA, (ii) the additional trade flow effect of RTAs that include SPS and TBT commitments, and (iii) a dummy variable that controls for RTAs that include any of the other twelve policy areas listed in Table 2. The equation is specified as follows:

$$\begin{aligned}\ln X_{ij,t} &= \beta_0 + \beta_1 \ln GDP_i, t + \beta_2 \ln GDP_j, t \\ &+ \beta_3 \ln D_{ij} + \beta_4 Contig_{ij} + \beta_5 lang_{ij} \\ &+ \beta_6 RTA_{ij,t} + \beta_7 topics_{ij,t} + \beta_8 SPS_{ij,t} + \beta_9 TBT_{ij,t} + \epsilon_{ij,t}.\end{aligned} \tag{3.9}$$

In equation (4) the variable RTA is a dummy variable equal to one if two countries belong to a mutual trade agreement in year $t$. The *topics* dummy variable is equal to one if the RTA includes commitments to liberalize any of the twelve policy areas except SPS and TBT, and zero otherwise. The dummy variables $SPS$ and $TBT$ equal one if the agreement includes commitments to liberalize or harmonize SPS and TBT policies within the RTA, and zero otherwise. Then lastly *contig* stands for contiguity–if the countries border each other–also a dummy variable, standing for 1 if they do and 0 if they do not. Then *lang* stands for 1 if they share the same language, and 0 if they do not. A bilateral trade agreement does not necessarily have to have an RTA, so we avoid falling into the dummy variable trap. Also, an RTA does not necessarily have to include any of the fourteen topics.

We address the potential problem of endogeneity through omitted variables or selection bias in $Topics$, $RTA$, $SPS$, and $TBT$ by using a comprehensive set of bilateral pair dummies advocated by Baier & Bergstrand (2007) and Baldwin & Taglioni (2006). The authors address a source of endogeneity bias, the unobservable heterogeneity among country pairs that is constant over time (such as distance, contiguity, and other dyadic-specific variables), by instead including bilateral pair dummies in their model. That is, there could be possible endogeneity due to omitted variables or selection bias. They explain that two countries that have a free trade agreement (FTA) (a type of RTA) tend to share similar economic characteristics such as GDPs, but can also have other economic characteristics that are not listed in the gravity model. For example, if two countries face similar negative barriers to trade that are not included in the gravity model, it would cause omitted variable bias, and the RTA coefficients would consequently be underestimated. Including these controls the gravity equation becomes:

$$\begin{aligned}\ln(X_{ijt}) = \alpha_0 + \gamma_{ij} + \gamma_{it} + \gamma_{jt} + \beta_6 RTA_{ij,t} + \beta_7 Topics_{ij,t} \\ + \beta_8 SPS_{ij,t} + \beta_9 TBT_{ij,t} + \varepsilon_{ijt},\end{aligned} \tag{3.10}$$

where $\gamma_{ij}$ are bilateral pair fixed effects and $\gamma_{it}$ are exporter by time dummies and $\gamma_{jt}$ are importer by time dummies. While the country-pair and country-by-time fixed effects (it, jt) address most of the concerns in the estimation of the gravity equation, a key issue remains and that is the omission of zero trade flows through log-linearization of the gravity equation. Below we discuss this type of bias and methods to circumvent it.

### 3.3.2 Correction for Zero Trade

When the trade flows between two countries is zero, those observations gets omitted due to the logged dependent variable. However, omitting zero trade flows can create selection bias. There are several reasons why zero trade flow can occur in the first place, that is, why do two countries opt out trading. First, two countries that are small and distant from one another, or ones that have large variable or fixed costs, are not likely to trade, even with the inclusion of an RTA, since no RTA could make the countries less distant or increase their size. By not including such observations, we *overestimate* the success of RTAs. Another possibility for zero trade is rounding errors. For example, if the measurements are in thousands of dollars, it is possible that for pairs of countries for which bilateral trade did not reach some minimum value (say, $500), the value of trade is registered as zero (Santos Silva & Tenreyro, 2006). This rounding down is most likely to occur for small or distant countries in which (for instance) the inclusion of an RTA contributed to going from zero trade to a positive trade. However, the probability that the trade gets rounded down to zero will depend on the covariates, in which case there is inconsistency in the estimators. Lastly, not all countries trade all products with all partners. Haveman & Hummels (2004) discuss such "incomplete specialization" as a reason for zero trade. However, with the signing of an RTA, the imports could become more favorable than the domestic products. This is an instance of where not including zero trade flow would *underestimate* the effect of an RTA. Hence dropping zero observations may create selection bias (Helpman Melitz & Rubinstein, 2008).

There has been a substantial amount of research done in trying to estimate the gravity equation by including observations with zero trade flows. One way to adjust for zero trade flows is to add 1 to each observation. Another is the Poisson Pseudo Maximum Likelihood estimator. We use the Poisson Pseudo Maximum Likelihood (PPML) estimator, as presented by Santos Silva & Tenreyro (2006), to correct for zeros in trade by using limited dependent variables and assigning the same weights to all observations. The authors point out that without knowing the pattern of heteroskedasticity, the PPML method is the best option. PPML is also consistent in the presence of fixed effects. The PPML model is estimated by solving the following first order conditions:

$$\sum_{ij}(X^{ij} - \exp(Z^{ij})\hat{\beta}) \tag{3.11}$$

where $ij$ denote the country pairs, $X^{ij}$ is the levels value of unidirectional exports, and $Z^{ij}$ is the full vector of gravity equation covariates, including RTA variables, and $E(\exp)$ is the expected value of the exponential function. The variables in $Z^{ij}$ can be in logarithms and the estimated coefficients can be interpreted as elasticities even though the dependent variable is in levels. Importantly, the PPML model produces consistent estimates provided, $E(X^{ij}|Z^{ij}) = \exp(Z^{ij}\hat{\beta})$ is satisfied even if the data are not count variables (Wooldridge, 2002). The PPML is an estimation that is robust to misspecification of error variance, as long as the conditional mean function is correctly chosen. However, if we have too many zeros, this will not be the case. The percentage of zero trade flows is less than 30% for both of our datasets, so bias in our estimates is unlikely. However, recent simulation evidence shows that the PPML performs strongly even in datasets with a large number of zeros (Santos & Tenreyro, 2011a).

### 3.3.3 Hypothesis Testing

In order to evaluate the degree of statistical difference between our two variables of choice – explicitly, RTAs including Topics and RTAs that do not include Topics – we perform hypothesis tests:

$$H_0 : RTA_k = RTA_{\not k}$$

$$H_A : RTA_k \neq RTA_{\not k}$$

where $k$ stands for one or more of the 14 policy areas that is covered by the agreement. We expect to find that $RTA_k$ is statistically different from $RTA_{\not k}$. For example, coefficients on RTAs that include all policy areas versus RTAs that do not include all policy areas should be statistically different. In the above notation, $RTA_k$ is initially assumed to be a dummy variable equal to one when the agreement includes trade liberalization commitments on at least one topic, and zero otherwise. $RTA_{\not k}$ is a dummy variable equal to one if the agreement contains no trade liberalization commitments on any topic. In this way we are able to test for differences in the trade creating ability of RTAs conditional on some form of trade liberalization being embodied in the agreement.

However, another way to test this hypothesis is to compute the mean number of topics covered by the RTA. Since there are 14 possible topics that could be included in any agreement, and presumably only the deepest RTAs cover all 14 topics, we construct a simple, unweighted ratio of the number of topics covered over the total number of topics by the agreement as a measure of the heterogeneity of trade liberalization commitments among the 96 RTAs included in the sample. Ideally, we should weight each topic by its relative importance in stimulating trade when constructing the mean. However, without any clear guidance from theory on the relative importance of each topic in terms of liberalizing trade, we proceed using a simple average.

## 3.4 Data

We compile two datasets: one labeled "World Trade", which includes total merchandise trade occurring between 1965 and 2010 for bilateral pairs in five year increments; and one labeled "Agricultural Trade", which runs from 1980 to 2008 in four year increments. There are 209 countries in the world trade dataset and 213 countries in the agricultural trade dataset. Both datasets are a combination of several sources. Trade data is based on countries' reported import notifications to the United Nations' Commodity Trade Statistics (Comtrade). Distance, common border, and language data is collected from *Centre d'Etudes Prospective et d'Informations Internationales* (CEPII), whose geo-distance dataset is developed by Mayer and Zignago (2006).[2] The WTO's *World Trade Report 2011*, the World Bank's (WB) World Development Indicators (WDI), and the United National Accounts Main Aggregate Database include data on GDPs.[3]

Comtrade data uses the Standard Industrial Trade Classification (SITC) product codes. Bilateral import values are collected on a nominal basis due to inappropriate deflation trade flows, which can be corrected using time-varying importer and exporter specific fixed effects (Baldwin & Taglioni, 2006). As advocated by Feenstra et al. (2005), mirrored trade flows are utilized when countries' imports are missing but the exporters' reported exports are positive. For the Agricultural Trade data set, the WTO's Multilateral Trade Negotiations (MTN) categories are used to classify agricultural goods, as documented in Grant (2013).

The WTO 2011 report has information on regional trade agreements, where our World Trade

[2] CEPII is an independent European research institute specializing in the international economy and stationed in Paris, France. For more information, see `www.cepii.com`.

[3] We use GDP data from Penn World Tables (PWT 6.3) to supplement WB and UN data where it is incomplete or missing. Development indicators are retrieved from `http://databank.worldbank.org/data/home.aspx`. UN GDP data can be retrieved from `http://unstats.un.org/unsd/snaama/dnllist.asp`. Penn World Tables can be accessed at the Center for International Comparisons at the University of Pennsylvania's website: `https://pwt.sas.upenn.edu/php_site/pwt_index.php`.

dataset includes 123 RTAs, and the Agricultural Trade dataset include 105 RTAs[5]. While WTO report reports 286 RTAs in force, there are many duplicates, and for our Agricultural Trade dataset we do not include all years as reported in the WTO report. Table 3.3 reports the number of observations for the two data sets and the number of observations in the variables we are most interested in. Under both datasets there is less than 30% of zero trade flows as presented in Table 3. SPS shows up less than TBT in a given trade agreement and RTAs are included in only 5% to 6% of trade for world trade and agricultural trade respectively.

Table 3.3: Summary statistics

| | World Trade (1965-2010) | | Agricultural Trade (1980-2008) | |
|---|---|---|---|---|
| | Observations | % of Total | Observations | % of Total |
| Total | 269,547 | | 179,723 | |
| Positive Trade Flow | 194,993 | 72% | 130,291 | 72% |
| Zero Trade Flow | 74,554 | 28% | 49,432 | 28% |
| RTAs | 13,170 | 5% | 10,340 | 6% |
| SPS | 5,214 | 2% | 3,784 | 2% |
| TBT | 6,803 | 3% | 5,185 | 3% |

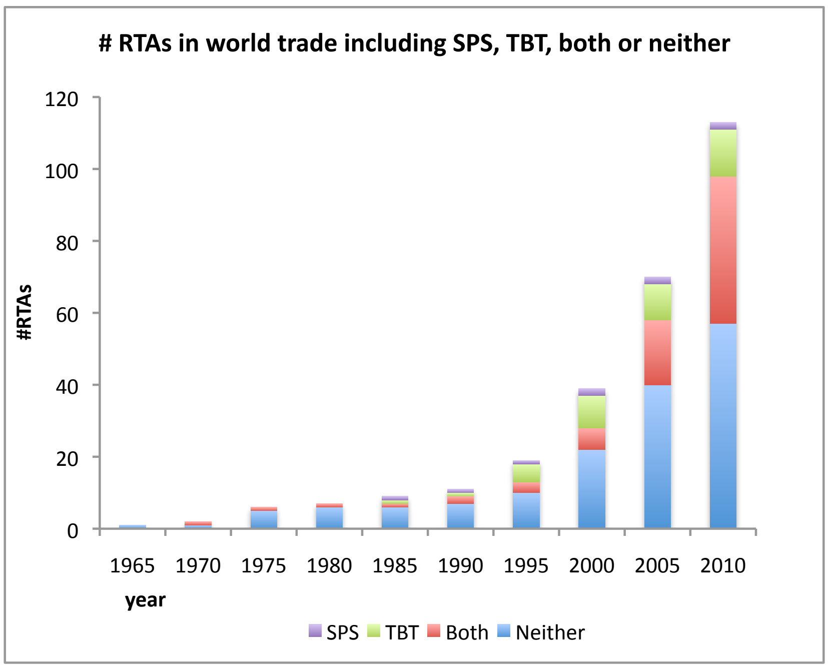
While the percent of RTA, SPS, and TBT over all trade flows is low, Figure 3.2 shows that the share of trade is significantly higher, implying SPS and TBT are significant contributors to large trade flows.

Figure 3.3 helps us better understand how the policy areas of SPS and TBT are represented in the two datasets. As can be seen from the figure, the number of RTAs increases over time, and each category of the four noted in the figure also increases over time. Most RTAs

[5]Available at: `http://rtais.wto.org/UI/PublicMaintainRTAHome.aspx`

in both data sets do not have either SPS or TBT, but the proportion of the ones that have at least one increase over time as well. Also noteworthy is that the sheer number of RTAs notified to the WTO seems to climb a cliff beginning in 2000. As a robustness check on the results,we will distinguish between "New RTAs" for those agreements that entered into force after 2000, and "Old RTAs" defined as those agreements that entered into force prior to the year 2000.

Figure 3.3: The number of RTAs for the two datasets given four conditions. (1) **Neither**: RTAs that do not have either SPS or TBT, (2) **Both**: RTAs that have both SPS and TBT, (3) **TBT**: RTAs that have only TBT but not SPS, and (4) **SPS**: RTAs that have only SPS and not TBT.




## 3.5 Results

The econometric results are organized into four sections. The first estimates benchmark results; that is, RTAs without dissecting them by the type of policy areas they include. The next section estimates RTAs with at least one policy area versus RTAs with no policy areas, as well as a specification that includes the simple average number of policy areas included per agreement. We do this for both data sets. In the third section, we look at the topics of SPS and TBT under the two datasets. The last section includes a set of robustness checks that hinge on the delineation of new, versus old, RTAs.

### 3.5.1 Benchmark Results

Table 3.4: Benchmark results

| | World Trade | | | Agricultural Trade | | |
|---|---|---|---|---|---|---|
| | Time FE | Country-Time FE | Bilateral pair and country by time FE | Time FE | Country-Time FE | Bilateral pair and country by time FE |
| lgdpi | 1.027*** | | | 0.697*** | | |
| | (0.00) | | | (0.01) | | |
| lgdpj | 0.848*** | | | 0.634*** | | |
| | (0.00) | | | (0.01) | | |
| ld | -1.085*** | -1.278*** | | -0.790*** | -1.121*** | |
| | (0.01) | (0.01) | | (0.02) | (0.01) | |
| contig | 0.615*** | 0.725*** | | 1.043*** | 0.848*** | |
| | (0.07) | (0.03) | | (0.08) | (0.04) | |
| lang | 0.815*** | 0.760*** | | 0.867*** | 0.760*** | |
| | (0.03) | (0.01) | | (0.03) | (0.02) | |
| RTA | 0.635*** | 0.315*** | 0.323*** | 0.612*** | 0.334*** | 0.381*** |
| | (0.03) | (0.02) | (0.02) | (0.04) | (0.02) | (0.03) |
| N | 182,244 | 194,993 | 194,993 | 126,622 | 130,060 | 130,291 |
| $R^2$ | .65 | .25 | .86 | .47 | .23 | .83 |
| Root MSE | 2.12 | 1.80 | 1.34 | 2.20 | 1.79 | 1.22 |

The Dependent variable is the natural logarithm of bilateral trade. Robust standard errors are in parentheses, except for the hypothesis test which is reported using $p$-values. Asterisks indicate significance at the (*) 10%, (**) 5%, (***) 1%. Columns 1 and 4 use time fixed effects, columns 2 and 5 use country by time fixed effects, and columns 3 and 6 use bilateral pair and country by time fixed effects.

Since this is a benchmark, we do not adjust for zeros in this first table. Under all specifications, RTAs increase trade flows, consistent with previous results. Under the most theoretically consistent specification, in which we account for multilateral resistance terms and possible bias from policy barriers correlating with RTAs (bilateral pair and country by time fixed effects), the results imply RTAs increase trade flows by $(e^{.323} - 1) * 100\% = 38\%$ for world trade and $(e^{.381} - 1) * 100\% = 46\%$ for agricultural trade. These benchmark results indicate that agricultural trade stands to benefit more from RTAs than world trade.

These results are also consistent with previous theory in that $\ln(gdp)$'s for the respective importer and exporter is close to 1 and $\ln(d)$, or the log of distance, is close to $-1$. In other words, trade flows are proportional to the trading countries' GDPs and inversely proportional to the distance between them. Also, a shared language and border increase trade flows, again consistent with previous findings.

In the next section, we continue studying RTAs by observing how any policy area included in an RTA affects trade flows.

### 3.5.2 All Policy Areas

Table 3.5: Policy area results

| | World Trade | | | | Agricultural Trade | | | |
|---|---|---|---|---|---|---|---|---|
| | Time FE | Country-Time FE #1 | Bilateral pair and country by time FE | Country-Time FE #2 | Time FE | Country-Time FE #1 | Bilateral pair and country by time FE | Country-Time FE #2 |
| $\ln(gdp_i)$ | 1.560*** | | | | 0.837*** | | | |
| | (0.01) | | | | (0.01) | | | |
| $\ln(gdp_j)$ | 1.291*** | | | | 0.733*** | | | |
| | (0.01) | | | | (0.01) | | | |
| $\ln(d)$ | -1.667*** | -1.903*** | | -1.895*** | -0.844*** | -1.201*** | | -1.206*** |
| | (0.03) | (0.01) | | (0.01) | (0.02) | (0.01) | | (0.01) |
| Contiguity | -0.042 | 0.173** | | 0.161** | 0.618*** | 0.747*** | | 0.757*** |
| | (0.15) | (0.06) | | (0.06) | (0.10) | (0.04) | | (0.04) |
| Language | 1.431*** | 1.446*** | | 1.443*** | 1.075*** | 0.869*** | | 0.875*** |
| | (0.05) | (0.02) | | (0.02) | (0.04) | (0.02) | | (0.02) |
| RTA with Policies | -0.038 | -0.237*** | 0.078*** | | 0.753*** | 0.296*** | 0.548*** | |
| | (0.06) | (0.04) | (0.05) | | (0.04) | (0.03) | (0.03) | |
| RTA without Policies | -0.644*** | -2.569*** | -0.780*** | -2.548*** | 1.437*** | -0.371*** | 0.016*** | -0.383*** |
| | (0.12) | (0.18) | (0.18) | (0.18) | (0.12) | (0.11) | (0.10) | (0.11) |
| Averaged Number of Policies | | | | -0.202** | | | | 0.432*** |
| | | | | (0.07) | | | | (0.05) |
| F-test | 24.28** | 159.47*** | 21.64*** | 149.02*** | 31.60*** | 34.95*** | 25.49*** | 47.97*** |
| Prob F | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) | (0.00) |
| N | 236,613 | 269,547 | 269,547 | 269,547 | 172,892 | 179,155 | 179,723 | 179,155 |
| $R^2$ | .53 | .13 | .78 | .13 | .46 | .18 | .80 | .17 |
| Root MSE | 4.57 | 3.75 | 3.25 | 3.75 | 2.777 | 2.20 | 1.71 | 2.20 |

The Dependent variable is the natural logarithm of bilateral trade. Robust standard errors are in parentheses, except for the hypothesis test, which is reported using $p$-values. Asterisks indicate significance at the (*) 10%, (**) 5%, (***) 1%. Columns 1 and 5 use time fixed effects; columns 2, 4, 6, and 8 use country by time fixed effects; and columns 3 and 7 use bilateral pair and country by time fixed effects.

Table 3.5 presents econometric results with robust standard errors in parentheses. We present both datasets: world trade and agricultural trade. We use several specifications to estimate, in particular using: time fixed effects, country by time fixed effects, and bilateral pair and country by time fixed effects. All specifications account for zero trade by adding 1 to the dependent variable. Economic size ($\ln(gdp_{i,j})$) is positive and statistically significant in all scenarios. Increasing the distance between an importer and an exporter reduces trade, while common language and a shared border increases trade, as expected.

RTAs that have at least one policy area in both datasets have a higher coefficient than those that do not for all specifications, except that of time fixed effects. However, this coefficient is not significant for world trade. In addition, under the theoretically consistent estimations for the two data sets, covering multilateral resistance terms (country-time fixed effects) and addressing potential endogeneity (bilateral pair fixed effects), RTAs that do cover policy areas are positive and consistent, and RTAs that do not cover any policy areas increase trade flows marginally for agricultural trade and actually *decrease* trade flows for world trade.

Under agricultural trade, RTAs that cover at least one policy area significantly increase trade flows under all specifications. This demonstrates that policy areas have a bigger impact on agricultural trade than world trade.

In both agricultural trade and world trade, under all four specifications, $RTA_k$ is statistically different from $RTA_{\not{k}}$ at the 1%. That is, where $RTA_k$ stands for an RTA that covers at least one policy area and $RTA_{\not{k}}$ an RTA not covering any policy areas. Thus, including commitments to liberalize trade in at least one policy area in an RTA significantly impacts trade flows.

Lastly, we examine the unweighted number of topics covered per agreement. This is shown in the final column for each database. Here, we see that the more policy areas included, the larger the increase in trade flows. That is, for world trade, the coefficient is less negative than that for RTAs that do not have any policy areas. This is an important result, since it suggests that the trade-creating benefits of RTAs are an increasing function of the depth of trade liberalization pursued by the agreement. Hence the larger the proportion of trade-liberalizing topics included, the greater the increase in trade flows for member countries.

From this section, we conclude that including policy areas in RTAs does increase trade flows. However, the impact of RTAs that do not cover any policy areas can actually decrease trade flows for world trade under the most theoretically consistent specification.

Next, we focus on two policy areas important for agri-food trade: SPS and TBT.

### 3.5.3 Main Results on Policy Areas: SPS and TBT

In Table 3.6, we look at what happens to trade flows under an RTA that covers SPS, one that covers TBT, and one that covers any number of the remaining twelve policy areas. We stick to the most theoretically consistent estimations – country-time fixed effects and bilateral pair and country by time fixed effects – and consider zero trade flows by including PPML. However, an important note is that we cannot include country by time fixed effects, only bilateral pair fixed effects, when using PPML. We once more look at both world trade and agricultural data.

Table 3.6: Main results on policy areas

| | World Trade | | | Agricultural Trade | | |
|---|---|---|---|---|---|---|
| | Country-Time FE | Bilateral pair and country by time FE | PPML | Country-Time FE | Bilateral pair and country by time FE | PPML |
| topics | 1.558*** | 0.535*** | -0.288*** | 0.314** | 0.459*** | 0.014 |
| | (0.19) | (0.19) | (0.04) | (0.12) | (0.12) | (0.67) |
| RTA | -2.59*** | -.802*** | 0.459*** | -0.373*** | 0.016 | 0.354*** |
| | (0.18) | (0.18) | (0.04) | (0.11) | (0.10) | (0.00) |
| SPS | -1.164*** | 1.051*** | 0.212** | -0.342*** | 0.484*** | 0.208** |
| | (0.12) | (0.14) | (0.09) | (0.07) | (0.08) | (0.04) |
| TBT | 2.099*** | -0.259* | -0.211** | 0.915*** | -0.240** | -0.150 |
| | (0.12) | (.14) | (0.09) | (0.07) | (0.08) | (0.14) |
| language | 1.467*** | | | 0.882*** | | |
| | (0.02) | | | (0.02) | | |
| contiguity | 0.178*** | | | 0.747*** | | |
| | (0.06) | | | (0.04) | | |
| $log(d)$ | -1.899*** | | | -1.120*** | | |
| | (0.01) | | | (0.01) | | |
| $log(gdpi)$ | | | 0.690*** | | | 0.272*** |
| | | | (0.04) | | | (0.00) |
| $log(gdpj)$ | | | 0.578*** | | | 0.466*** |
| | | | (0.04) | | | (0.00) |
| $N$ | 269,547 | 269,547 | 234,103 | 179,155 | 179,723 | 167,910 |
| $R^2$ | .25 | .78 | | .17 | .80 | |
| Root MSE | 3.24 | 1.33 | | 2.208 | 1.71 | |

The Dependent variable is the natural logarithm of bilateral trade. Robust standard errors are in parentheses, except for the hypothesis test, which is reported using *p*-values. Asterisks indicate significance at the (*) 10%, (**) 5%, (***) 1%. Columns 1 and 4 use country by time fixed effects, columns 2 and 5 use bilateral pair and country by time fixed effects, and columns 3 and 6 use PPML, which does *not* account for country by time fixed effects.

All specifications except for PPML add 1 to flows and then take the natural logarithm to account for zero trade flows. The bilateral pair and country by time fixed effects estimation is the most theoretically consistent, since it accounts for all possible endogeneity bias: selection bias from not accounting for zero trade, unobserved policy barriers that may correlate with the choice to enter into an RTA, and multilateral resistance terms. Under this specification, *topics* significantly increase trade flows in addition to the RTA dummy for both specifications: $(e^{.535} - 1) * 100\% = 71\%$ for world trade and $(e^{.459} - 1) * 100\% = 58\%$ for agricultural trade. While the RTA dummy does not increase world trade, it is not significant for agricultural trade. However, this emphasizes that the main reason for such large increases in trade flows is the additional *topics* that can be included in the RTA. Also, this result is consistent with Table 3.5 – RTAs without any topics can actually *decrease* trade flows for world trade.

For the two topics of interest, SPS and TBT, SPS increases trade substantially in both data sets, and TBT actually decreases trade flows for the two datasets. Thus an RTA that includes SPS, TBT, and any of the twelve topics for world trade will increase trade flows by $(e^{.535-.802+1.051-.259}-1)*100\% = 69\%$ and for agricultural trade by $(e^{.459+.484-.24}-1)*100\% = 101\%$, which is again consistent with Table 3.5 – RTAs that include topics in agricultural trade benefit more than RTAs that include topics for world trade.

For the PPML specification, the results suggest that RTAs significantly increase trade for both datasets: by $(e^{.458} - 1) * 100\% = 58\%$ for world trade and $(e^{.354} - 1) * 100\% = 42\%$ for agricultural trade, which is consistent with previous results. In terms of RTAs that include SPS and TBT commitments, we see that an RTA that covers SPS measures increases trade flows by an additional $(e^{.212} - 1) * 100\% = 24\%$. However, TBT decreases trade flows for world trade, along with the other twelve policy areas under *topics*. This is consistent with the bilateral pair and country by time fixed effects specification. However, this specification does not account for multilateral resistance terms, and this could be the reason for the discrepancy in the *topics* coefficient.

When examining agricultural trade, the remaining twelve topic areas included in the variable *topics* are not significant, and neither is the TBT variable. The two significant coefficients, $SPS$ and $RTA$, are positive and show that for agricultural trade, not only do RTAs increase trade, but RTAs that include the policy areas of SPS increase trade flows even further. That is, for agricultural trade, including SPS increases trade flows by an additional $(e^{.208} - 1) * 100\% = 23\%$. Just including an RTA increases trade by $(e^{.354} - 1) * 100\% = 42\%$. Hence the total increase in trade flows is 65% from an RTA that includes SPS.

Under country time fixed effects, we find that SPS can actually reduce trade flows, while TBT can increase trade flows. However, this specification does not control for natural trading partner effects and the endogeneity concerns raised in Baier and Bergstrand (2007) and Baldwin and Taglioni (2006). It does confirm that including up to twelve policy areas under *topics* causes trade flows to increase, and those are what drive the majority of the increase; that is, not just an RTA, but an RTA that includes policy areas, will markedly increase trade flows.

All of these results are consistent in that not all RTAs increase trade flows equally. That is, RTAs significantly increase trade flows when including SPS and any of the other twelve topics. In particular, SPS liberalizes trade the most and thus increases trade flows the most.

### 3.5.4 Robustness Checks

Table 3.7: Robustness checks: new vs. old RTAs

| | World Trade | | Agricultural Trade | |
|---|---|---|---|---|
| | RTAs Before 2000 | RTAs After 2000 | RTAs Before 2000 | RTAs After 2000 |
| topics | 2.056*** | 0.665** | 0.419*** | 0.667* |
| | (0.00) | (0.00) | (0.01) | (0.03) |
| RTA | -2.431*** | | -0.591*** | |
| | (0.00) | | (0.00) | |
| SPS | -0.969*** | 0.653*** | -0.174 | 0.348** |
| | (0.00) | (0.00) | (0.07) | (0.02) |
| TBT | 1.857*** | -0.407* | 0.864*** | -0.387** |
| | (0.00) | (0.01) | (0.00) | (0.03) |
| language | 0.737*** | 0.608*** | 0.698*** | 1.128*** |
| | (0.00) | (0.00) | (0.00) | (0.00) |
| contiguity | 0.760*** | 0.414*** | 0.840*** | 0.613*** |
| | (0.00) | (0.00) | (0.00) | (0.00) |
| $log(d)$ | -1.297*** | -1.323*** | -1.137*** | -1.326*** |
| | (0.00) | (0.00) | (0.00) | (0.00) |
| $N$ | 177124 | 5120 | 122012 | 4610 |
| $R^2$ | .24 | .24 | .21 | .24 |
| Root MSE | 1.80 | 1.18 | 1.79 | 1.32 |

The dependent variable is the natural logarithm of bilateral trade. Robust standard errors are in parentheses, except for the hypothesis test, which is reported using $p$-values. Asterisks indicate significance at the (*) 10%, (**) 5%, (***) 1%. All columns use country by time fixed effects.

As seen in Table 3.7, for robustness checks, we use country time fixed effects to account for multilateral resistance terms. The results show that, for RTAs created after 2000 (“new” RTAs), including SPS measures increases trade flows significantly. In fact, before 2000, for both datasets, RTAs *reduced* trade flows, and only the inclusion of policy areas (all but SPS) led an RTA to actually increase trade flows. This could be the reason why previous studies that only focused on RTAs created before 2000 showed positive coefficients for RTAs. That is, it was the thirteen policy areas that actually liberalized trade and led to large increases in trade flows.

After 2000, all RTAs that came into force started including at least one policy area, and that is why $RTA$ is dropped. However, for RTAs that joined after 2000, the results confirm the findings depicted in Table 3.6; namely, that RTAs that include SPS increase trade, whereas TBT can actually decrease trade flows. We can also conclude that policy areas are a large part of the reason for increases in trade flows. That is, including any of the other twelve topics in an RTA will increase trade flows significantly.

## 3.6 Conclusion

We have estimated the effects of RTAs on total merchandise and agricultural trade by decomposing them based on which policy areas they include. We have focused on two policy areas: SPS and TBT safety measures. We have found that SPS, in particular, increases trade flow for both datasets more than TBT. More precisely, agricultural trade flows increase by 101% if an RTA includes SPS, TBT and any of the other 12 topics. If, however, an RTA does not include SPS but includes TBT and any of the other 12 topics, it would cause only a 24% increase in agricultural trade flows, as presented in Table 3.6. Thus, RTAs that include SPS safety measures under their agreement would increase their trade flows for agricultural goods. SPS also impacts world trade, but to a lesser extent; that is, RTAs with SPS, TBT, and any of the other 12 topics increase trade flows for world trade by 69%. However, due to a significant TBT coefficient, that is negative, the positive SPS coefficient does not significantly increase trade flows. Thus the overall effect of RTAs on world trade flows much less than in agricultural trade, since an RTA that does not include any of the topics actually decreases trade flows by $\exp^{-.802} - 1 * 100 = 123\%$.

Lastly, in agricultural trade, RTAs that include SPS have a clear advantage over RTAs that do not. Since SPS safety measures affect agricultural goods, we conclude that to study the importance of these policy areas in RTAs, we must decompose world trade into correct subsets (agriculture, manufacturing, etc.) and analyze the particular policy areas that affect those subsets. This can be extended to further research. For example, the study of countervailing measures and antidumping can be extended to manufacturing trade, since both measures deal with undercutting the cost of production.

Nonetheless, we conclude that once RTAs are decomposed into policy areas and the appropriate policy areas are tested for (SPS in our case), RTAs that cover those policy areas make a substantial contribution to trade flows. We also conclude that not all RTAs have the same effect on trade flows, since RTAs in agricultural trade that include SPS increase trade flows more than those that do not. On a larger scale, RTAs that cover at least one of the other twelve policy areas examined in this study increase trade flows by more than those RTAs that cover no policy areas. Hence agricultural trade stands to benefit the most from the inclusion of policy areas, and SPS in particular has a significant increase in trade flows for both datasets. Thus, in future RTAs, it is recommended that SPS safety measures be included in order to secure an increase in trade flows.

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# CHAPTER 4

# ESSAY 3: ESTIMATING WHETHER MEMBERSHIP IN THE WTO INCREASES TRADE USING BAYESIAN MODEL AVERAGING

## 4.1 Abstract

Existing GATT/WTO literature is not univocal as to whether membership in the GATT/WTO increases trade flows. Bayesian model averaging (BMA) is used in the presence of theoretical uncertainty in this study to address whether membership in the GATT/WTO belongs in the gravity model. We look at several datasets: a dataset of a previous study; and two datasets compiled for this study, world trade and agricultural trade. We find, for all three sets of data, that membership in the GATT/WTO has a high probability of being included in the gravity equation and increases trade flows.

## 4.2 Introduction

In this paper, we evaluate the effect of membership in the World Trade Organization (WTO) and its predecessor, the General Agreement on Tariffs and Trade (GATT), on trade flows via the gravity equation using Bayesian Model Averaging (BMA) as our estimation technique. Secondly, we evaluate the effect of other trade barriers and facilitators commonly used in the gravity equation on trade flows.

Membership in the GATT/WTO, an organization that aims to facilitate trade, is a regressor in the gravity equation, that is not always used in the gravity equation due to the lack of univocal contributions to trade flows. GATT originally formed in 1948 to establish a strong and prosperous multilateral trading system that became more liberal through rounds of negotiations. The Uruguay Round (1986-1994)[1], brought on the most recent changes in which the name changed from GATT to WTO and brought on a new set of agreements.

Currently the WTO is in ongoing multilateral negotiations under the Doha Round, started in 2001. The purpose of the WTO is to help trade flow as freely as possible, provided there are no undesirable side effects, such as increased protectionism, and to control for economic development and well-being of those in the WTO. Rose (2004a), a pioneer in WTO literature, has found that the WTO has no effect on trade flows, even when the WTO claims that it liberalizes trade and makes trade stable and predictable[2]. However, Rose (2004a) uses basic parametric estimation techniques to estimate the effects of the WTO on trade flows. This paper, in contrast, attempts to use an alternative approach (BMA) to determine whether the WTO impacts trade flows. That is, BMA, examines all possible models with all of the possible regressors relevant to trade literature, to have an averaged model, that either has

[1] http://www.wto.org/english/thewto_e/whatis_e/who_we_are_e.htm

[2] http://www.wto.org/english/thewto_e/whatis_e/inbrief_e/inbr00_e.htm
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a high probability of including membership in the WTO, or a low probability. While Rose (2004a) examines over 80 specifications, there might not be one perfect model. Thus he might have not considered the best suited model in estimating trade flows via the gravity equation, and thus incorrectly estimated the coefficient on membership in the WTO. However, BMA averages over all the models, with relevant probabilities, and provides an averaged result over all these models.

The empirical study of the effects of the WTO on trade flows is fairly new. Rose (2004a) used a standard gravity model of bilateral trade and augmented it with additional controls: *bothin* and *onein*, corresponding to whether both bilateral pairs are in the WTO, or just one country is in the WTO, respectively. He was surprised to find that *bothin* was not only not significant, but also negative. This precipitated a slew of studies in the WTO literature. Rose (2004b) followed, estimating almost 70 measures of trade policy and liberalization, and found that GATT, was not associated with more liberal trade policy. He studied the second moment of trade flows, again finding little evidence of any large membership effect (Rose, 2005a), and also compared GATT/WTO effect with the international monetary fund (IMF) and the Organization for Economic Cooperation and Development (OECD) (Rose, 2005b). He found membership in the OECD had a large positive effect, as did accession to, but not membership in, GATT/WTO.

However, following Rose, there were several studies that used different specifications to examine the effect of the GATT/WTO membership. Subramanian & Wei (2007) find that using industrial country importer fixed-effects shows a coefficient of *bothin* as positive and significant, yet find that it is insignificant when analyzing agricultural trade. Which can be explained by agricultural protectionism. Most recently, Grant & Boys (2012) found *bothin* positive and significant, when including more agricultural goods in the dataset, that is, focusing on all agricultural trade, not just a few highly protected products. Engelbrecht

& Pearce (2007) find that membership in the WTO is only increase trade flows for capital intensive commodities, but not for other commodities. Tomz., et al (2007) find that including non-formal members of the GATT produces a positive and significant *bothin* coefficient. Then Eicher & Henn (2009) compare the studies of Rose (2004a), Subramanian & Wei (2007) and Tomz., et al (2007) and find that all three studies suffer from omitted variable bias and find that membership in the WTO does not affect trade flows. Roy (2011) also finds that correcting for zero trade and multilateral resistance terms, while using Tomz., et al (2007) definitions for "formal members", membership in the WTO does not increase trade flows. Herz & Wagner (2007) showed that the level of the income of the members of the WTO effect trade flows differently. That is, imports from a high, middle, or low income country will result in different trade flows effects than when these countries are reversed. Nevertheless, they find that if both countries are in the WTO, trade flows will increase, and will increase to a lesser extent if only the importing country is in the WTO. Balding (2010), on the other hand, later found that the WTO has a greater impact on exports rather than imports. Liu (2009) finds that estimating correctly for zero-trade flows also produces a positive and significant coefficient. Several other studies (Felbermayr & Kohler, 2010; Helpman et al, 2008) also find that ignoring zero-trade flows biases the estimate downward. Thus once corrected for *bothin* is positive. However, even then Eicher & Henn (2009) found that once multilateral resistance terms, unobserved bilateral heterogeneity, and allowing for individual trade effects of PTAs, there is no WTO effect. While several methodologies (increasing the dataset, examining industrialized countries, correcting for zero trade, etc.) have been used to study the effects of membership in the WTO, BMA has yet to be used in the WTO literature, a gap we hope to fill.

Further, there are still contradictory results about which bilateral trade costs or facilitators to include in gravity models. The bilateral trade costs or facilitators in the gravity literature can depend on natural barriers, such as bilateral distance, adjacency, land border, etc.; manmade trade costs, such as free trade agreements (most importantly, in our case, membership in the WTO); and cultural barriers, such as common language, religion, etc. (Baldwin & Taglioni, 2006). Trade barrier dummies included can range from including only one dummy, such as language, to including up to 16 dummies, including colonial relationships, adjacent border, etc. , which is most commonly found in the trade literature. Being a member in WTO is most often excluded, due to the lack of consensus on its affect on trade flows. The significance of these trade barriers and facilitators may vary; for example, Mayer & Ottaviano (2007) and Lawless (2010) find that language is not statistically significant in contrast to Cozet & Koenig (2010), who find that to speak French has a positive and statistically significant coefficient. These authors also find that, adjacency is also not statistically significant, while Grant & Lambert (2008) find that both adjacency and language are statistically significant. Thus we use the results provided by the BMA to examine which of these trade barriers or trade facilitators are most relevant in the gravity model and thereby improve upon the estimation of the gravity equation, in particular in the WTO literature. That is, BMA addresses model uncertainty by addressing all possible combinations of the regressors we are trying to study. The direct approach to do inference on a single linear model that includes all variables can be inefficient or even infeasible with a limited number of observations, (Zeugner, 2012). However, BMA approaches the problem by estimating models for all possible combinations of regressors in question, and then its results are a weighted average over all the possible models.

BMA is an estimation technique that addresses model uncertainty in a linear regression problem. BMA solves the problem of uncertainty by estimating models for all possible combinations of the regressors and constructing a weighted average over all possible models. Since there is so much uncertainty regarding the gravity model regressors and in particular the inclusion of membership in the GATT/WTO, applying BMA is a reasonable strategy for dealing with this uncertainty. The newest paper that studies the model space – that is, that compares all the different possible models of the gravity equation – is the paper of Ghosh & Yamarik (2004). However, these authors only consider models that contain a specific number of fixed variables, to which a specific number of regressors is rotated in and out across models. This limits the search for the exact model to an undesirably small part of the model space. In contrast, BMA examines the entire model space and forces no restrictions on the size of the model to be considered.

We are not the first to apply Bayesian approaches to the gravity equation. Guo (2010) uses a hierarchical Bayesian method for the gravity equation to determine in which ways fixed-effects should be included in the gravity model to control for countries' business cycle properties. More precisely, the method determines whether or not the gravity model should include time-varying or time-invariant dummies, nation or separate importer and exporter dummies, and symmetric or asymmetric pair dummies. Guo estimates nine models using the Bayesian method and investigates the posterior distributions of the variance parameters of these models, finding that the constant importer and exporter effects model is favored. However, he finds no deterministic evidence for or against time-varying country dummies.

Eicher, Henn & Papageorgiou (2012) are also pioneers in estimating the gravity model via Bayesian statistics. They use BMA to find the effects of preferential trade agreements (PTAs) on trade flows. The authors find that, contrary to suggestions of previous studies, PTAs do affect trade creation and diversion. While they were able to look at 13 PTAs they did not consider membership in the WTO as a regressor. This regressor however, is very important for policy makers and the global economy, and thus should be estimated via BMA to examine if it should be included in the gravity model. Their work, however, indicates that BMA is a very important new tool that can be used to estimate the gravity model.

In Section 2 we introduce the conceptual model, followed by a data description in Section 3. Results are listed in Section 4, and concluding remarks can be found in Section 5.

## 4.3 Conceptual Model

### 4.3.1 Gravity Equation

The gravity equation measures trade flows as a function of the GDPs of trading countries and trade barriers or facilitators, one of which has been found to have conflicting results – namely, membership of the country pairs in GATT/WTO, Rose (2004a). That is, current research has not been univocal on whether membership in the GATT/WTO actually increases trade flows.

The gravity equation has been called “the workhorse of empirical studies to the virtual exclusion of other approaches” (Eichengreen & Irwin, 1998). The gravity equation was originally introduced by Tinbergen (1962), and while the model worked very well in estimating trade flows, the economic theory behind the gravity model was not fully developed. Tinbergen (1962), who drew upon Newton’s ‘Law of Universal Gravitation’, which states that the force of gravitational attraction between objects $i$ and $j$ can be written in the form

$$F_{ij} = G\frac{M_i M_j}{D_{ij}^2}. \tag{4.1}$$

In the gravity model, $F_{ij}$ is the ”monetary flow” from origin $i$ to destination $j$; $M_i$ and $M_j$ are the relevant economic sizes of the two locations (usually their gross domestic products (GDPs)); $D_{ij}$ is the distance between the locations; and $G$ is an appropriate force constant, which can consist of other barriers and facilitators relating to trade flows as discussed in the data section.

Thus the economic theory behind the gravity equation was first introduced by Anderson (1979), who used the constant elasticity of substitution (CES) expenditure system to construct it. Further improvements were made by Bergstrand (1985), Helpman (1987), and Deardorff (1998). The most recent contribution to the gravity model is the introduction of multilateral resistance terms by Anderson & van Wincoop (2003). These multilateral resistance terms are costs that the importer and exporter face in their trade with all of their trading partners. That is, the cost of trading between country $i$ and country $j$ also depends on how costly it is for country $i$ and country $j$ to trade with the rest of the world. Because of Anderson & van Wincoop (2003) findings, the gravity equation is now also a function of prices (of exports and imports) faced by the bilateral partners entering into the agreement and the rest of the world. Thus the basic gravity equation predicts that trade flows from country $i$ to country $j$ in year $t$ are proportional to the multiplicative interaction of each country's size, (GDPs), and inversely proportional to the distance between them:

$$X_{ijt} = \beta_0 Y_{it}^{\beta_1} Y_{jt}^{\beta_2} D_{ij}^{\beta_3} \epsilon_{ijt} \tag{4.2}$$

where $\beta_0$, $\beta_1$, $\beta_2$ and $\beta_3$ are unknown parameters, and $\epsilon_{ijt}$, is a multiplicative, stochastic error term.

Anderson & van Wincoop (2003) suggest using importer and exporter fixed effects for ease of estimation to account for multilateral resistance terms. We use the remoteness variable to serve as the proxy for the "index of multilateral resistance" since we cannot easily use importer and exporter fixed effects under BMA due to computer memory confinements. The "remoteness" is defined as the distance to the rest of the world weighted by all other countries' GDPs in a given year. We use the remoteness variable for a country pair $i$ and $j$

in year $t$ as presented by Liu (2009):

$$Remote_{ijt} = \left( \frac{\sum_{m \neq i} Distance_{mi} GDP_{mt}}{\sum_{m \neq i} GDP_{mt}} \right) \left( \frac{\sum_{m \neq j} Distance_{mj} GDP_{mt}}{\sum_{m \neq j} GDP_{mt}} \right). \tag{4.3}$$

Taking logs, this gravity equation can then be represented in its econometric form as follows:

$$\begin{aligned} \ln V_{ij} = \beta_0 + \beta_1 \ln GDP_i + \beta_2 \ln GDP_j \\ + \beta_3 \ln D_{ij} + \beta_4 \widetilde{Z}_{ij} + \epsilon_{ij}, \end{aligned} \tag{4.4}$$

where $V_{ij}$ is the value of trade from country $i$ to country $j$; $GDP_i$ ($GDP_j$) is the gross domestic product of the exporting (importing) country as a proxy for economic size; and $D_{ij}$ is the distance between countries $i$ and $j$, a proxy for transportation costs and one component used as a trade barrier. The other trade barriers/facilitators (presented in table 1), $Remoteness_{ijt}$ are captured by the $\widetilde{Z}$ matrix, including *bothin, onein*. The regressors of *bothin, onein* are of most importance to us since they measure the importance of membership in the WTO in the gravity model.

### 4.3.2 Bayesian Approaches

For a linear regression given a dependent variable $Y$, $n$ observations, and a set of $n \times 1$ candidate regressors $X_1, X_2, \ldots X_k$, we can write:

$$Y = \alpha + \sum_{j=1}^{p} \beta_j X_j + \epsilon, \tag{4.5}$$

where $1 \leq p \leq k$, $\beta$ is a vector of coefficients to be estimated and $k$ is the total number of regressors.

The following Bayesian modeling approach deals with an array of candidate models. In our trade barrier/facilitator estimation, the model space consists of all possible subsets of candidate regressors that have been suggested by the theories above. A model starts with $p(y|M_m)$ as the marginal likelihood for model $m$, $p(M_m)$ the model prior, and the complete model space as $M = M_1, M_2, \dots M_M$. Then the posterior model probabilities can be derived as:

$$p(M_m|y) = \frac{p(y|M_m)p(M_m)}{\sum_{j=1}^{M} p(y|M_j)p(M_j)}. \tag{4.6}$$

using Bayes theorem. If the model priors are the same for all models, because we want to start with the same probabilities for all models, and let the algorithm decide which models are selected (further discussed in detail), (4.6) further simplifies to

$$p(M_m|y) = \frac{p(y|M_m)}{\sum_{j=1}^{M} p(y|M_j)}. \tag{4.7}$$

A model-averaged posterior distribution for parameters $\theta$, where $\beta_j \in \theta$, can then be obtained via

$$p(\theta|y) = \sum_{m=1}^{M} p(\theta|y, M_m)p(M_m|y). \tag{4.8}$$

BMA first estimates the posterior distribution $p(\theta|y, M_m)$, for every candidate regressor $j$ where $\beta_j \in \theta$, in every model, $M_m$, that includes $\beta_j$. That is, using Bayes Theorem:

$$p(\theta|y, M_m) = \frac{p(y|\theta, M_m)p(\theta|M_m)}{p(y|M_m)} \propto p(y|\theta, M_m)p(\theta|M_m) \tag{4.9}$$

where $p(y|M_m)$ is the marginal likelihood, it is not a function of $\theta$, and can be usually ignored for most components of Bayesian analysis. Thus we work with only the numerator for inference about $\theta$, that is the expression is proportional to the actual posterior. $p(y|\theta, M_m) = (2\pi)^{-n/2}(\sigma^2)^{-n/2}\exp\left(-\frac{1}{2}(y - X\beta)'(y - X\beta)\right)$ for a "Classical Linear Regression Model", and the priors for $\beta, \sigma^2 \in \theta$ is $p(\beta, \sigma^2) = p(\beta)p(\sigma^2)$. Where $\beta \sim n(\mu_0, V_0)$ and $\sigma^2 \sim (ig(v_0, \tau_0))$, $v_0$ is the shape parameter, and $\tau_0$ is the scale parameter for an inverse gamma. Thus

$$p(\beta) = (2\pi)^{-k/2}|V_0|^{-1/2}\exp\left(-\frac{1}{2}(\beta - \mu_0)'V_0^{-1}(\beta - \mu_0)\right)$$

$$p(\sigma^2) = \frac{\tau^{v_0}}{\Gamma(v_0)}(\sigma^2)^{-(v_0+1)}\exp(-\frac{\tau_0}{\sigma^2})$$

Thus

$$p(\beta, \sigma^2|y, M_m) \propto (\sigma^2)^{\frac{-n-2v_0-2}{s}}\exp\left(-\frac{1}{2}\left(\frac{1}{\sigma^2}(y - X\beta)'(y - X\beta) + (\beta - \mu_0)'V_0^{-1}(\beta - \mu_0)\right)\right)$$

where once again $\beta, \sigma^2 \in \theta$. This can be computed by obtaining a large user-specified number of draws of $p(\theta|y, M_m)$ for each model, and then drawing from these model specific posteriors with relative frequency dictated by the computed model weights. That is, each model is weighted by its posterior model probability, $p(M_m|y)$, which gives the model averaged result. The posterior inclusion probability of a regressor is the probability that the corresponding variable is included in a given model. It makes a statement regarding the importance of a regressor that directly addresses the researcher's prime concern: What is the probability that the coefficient has a nonzero effect on the dependent variable? The posterior inclusion probability thus also carries an important interpretation that goes beyond the information contained in a standard P-value (Eicher, Henn & Papageorgiou, 2012).

For a small number of variables it is much easier to enumerate all potential variable combinations to obtain posterior results. However we have up to 28 regressors, including "remoteness" in a given model and up to 9 time-dummies, which can make it infeasible to consider all possible models, that is $2^{28}$. There are two most common approaches to model searching: Stochastic Search Variable Selection (SSVS) and Markov-Chain-Monte-Carlo (MCMC). We choose MCMC because in contrast to SSVS method, the posterior draws of model parameters are already "model averaged", SSVS, on the other hand, does not lend itself to a direct derivation of model-averaged posterior distributions. That is, SSVS gives information that can be then used to compute posterior inclusion probabilities for each coefficient and posterior model probabilities, but does not give the model averaged result. Thus we use MCMC sampler to obtain the results for the most important part of the posterior distribution and approximate it as close as possible. We use the Metropilis-Hastings algorithm, which examines the model space as follows:

At step $i$ the sampler stands at a certain 'current' model $M_i$ with posterior model probability (PMP) $p(M_i|y, X)$. In step $i + 1$ a candidate model $M_j$ is proposed. The sampler switches from the current model to model $M_j$ with probability $p_{ij}$:

$$p_{ij} = \min(1, p(M_j|y, X)/p(M_i|y, X))$$

In case model $M_j$ is rejected, the sampler moves to the next step and proposes a new model $M_k$ against $M_i$. In case $M_j$ is accepted, it becomes the current model and has to survive against further candidate models in the next step. Following this algorithm the number of times each model is kept will converge to the distribution of posterior model probabilities $p(M_i|y, X)$. (Zeugner, 2012).

The general rule for inclusion probabilities, developed by Jeffreys (1961) and later refined by Kass & Raftery (1995), provides effect thresholds for posterior probabilities. Posterior probabilities $< 50\%$ are seen as evidence against the effect. Evidence for an effect is either weak, positive strong, or decisive for posterior probabilities ranging from $50-75\%$, $75-99\%$, and $> 99\%$, respectively. In our analysis, we refer to a regressor as "effective" if its posterior inclusion probability exceeds 50%.

As described by Eicher, Henn & Papageorgiou (2012), BMA has many advantages over traditional econometric approaches: It minimizes the total error rate and the sum of Type I and Type II error probabilities. The point estimates and predictions minimize the mean squared error (MSE), and predictive distributions have optimal predictive performance relative to other approaches. We use BMA to evaluate which trade barriers/facilitators are most important in the gravity model as well as whether *bothin* and *onein* belong in gravity model.

### 4.3.3 Specifications

The study of estimating trade flows via the the gravity equation involves fixed effects estimators. We use two most common specifications: time fixed effects for the first specification (Feenstra, 2003) and country-pair and time fixed effects for the second specification. Hummels & Levinshon (1995) first introduced country-pair fixed effects into the gravity equation to distinguish between factor endowments and market structure as trade flow drivers. Also, Egger (2003) use country-pair fixed effects to account for heterogeneity from time-invariant factors such as geography and culture, which are only partially accounted for by the regressors or are unobserved. That is, by using fixed effects we now increase the number of regressors in the model from time dummies used for time fixed effects estimation. Since in our data we have up to ten years, our model is increased by up to nine regressors.

We also adjust for zero trade. The dependent variable is logged, however, when trade flows are zero, the observations become missing. There has been a substantial amount of research done in trying to estimate the gravity equation by including observations with zero trade flow. There are several reasons why zero trade flow can occur. First, two countries that are small and distant from one another, or ones that have large variable or fixed costs, are not likely to trade. By not including such observations, we overestimate the success of membership in the WTO. Another possibility for zero-trade is rounding errors. For example, if the measurements are in thousands of dollars, it is possible that for pairs of countries for which bilateral trade did not reach some minimum value (say, $500), the value of trade is registered as zero (Santos Silva & Tenreyro, 2006). This rounding down is most likely to occur for small or distant countries in which (for instance) membership in the WTO contributed to going from zero trade to a positive trade flow. However, the probability that the trade flow gets rounded down to zero will depend on the covariates, in which case there is inconsistency in the estimators. Lastly, not all countries trade all products with all partners, Haveman & Hummels (2004) discuss such "incomplete specialization" as a reason for zero trade. We adjust for zero trade flows, by adding a small value to all trade flows.

## 4.4 Data

We analyze three datasets: Rose (2004a) dataset, and our two compiled datasets: World Trade and Agricultural Trade data. First we analyze Rose (2004a) dataset, to stay consistent with the literature. Then we address our compiled two datasets, while adjusting for zero trade, to understand the effect of membership in the WTO under all sectors of trade, as well as agricultural data, in which two contradicting findings were discovered: Subramanian & Wei (2007) found *bothin* to be insignificant, whereas, most recently Grant & Boys (2012) found *bothin* significant and positive. We apply BMA to all three datasets and specifications.

We start by describing Rose (2004a) dataset, which we gather from his website. Their data set runs from 1948-2000, in one year increments, with a total of 497,548 observations.

Table 4.1: Rose data: variable description

| | | based on past studies | Variable description |
|---|---|---|---|
| | | Sign | |
| **Core Gravity** | lgdpi | (+) | log of GDP of exporting ctry in Mil. |
| | lgdpj | (+) | log of GDP of importing ctry in Mil. |
| | ld | (-) | log of distance between ctrys (km) (weighted by important cities in terms of pop) |
| **Geography** | LandLockij | (+/-) | =1 if one is, and 2=if both are landlocked |
| | landap | (+) | product of land areas |
| | borderji | (+) | 1=if importer and exporter share land border |
| | Islandij | (+/-) | 0=if neither is island; =1 if one is, and =2 if both are island ctrys |
| **Historical Ties** | comlangij | (+) | 1=if importer and exporter speak same language |
| | Colony | (+) | 1=if importer and exprter have ever had colonial relationship |
| | Comcolij | (+) | 1=if importer and exporter were colonized by same ctry |
| | Curcolij | (+/-) | are currently in a colonial relationship |
| | Col45 | (+) | 1=if importer and exporter have had a colonial relationship after 1945 |
| | defp1 | (+/-) | population in country i |
| | defp2 | (+/-) | population in country j |
| | indc2 | (+) | country j is industrialized |
| | indc2 | (+) | country I is industrialized |
| | custrict | (+) | 1= if strict currency union |
| | cpi | (+/-) | consumer price index |
| | $Comctry_{ij}$ | (+) | 1=if importer and exporter were ever the same country |
| **WTO** | gsp | (+/-) | 1= if either country is in GSP |
| | gw2 | (+/-) | 1= if country j is in GATT/WTO |
| | gw1 | (+/-) | 1= if country i is in GATT/WTO |

This table was compiled using Table 2 in Eicher, Henn & Papageorgiou (2012). The definitions were retrieved from Rose (2004a)

Other than examining membership in the GATT/WTO, Rose (2004a) also studied the Generalized System of Preferences (GSP), a formal system of exemptions from the WTO/GATT provided mostly to lower tariffs for the least developed countries without lowering tariffs for richer countries.

Next, we compile two datasets, one labeled World Trade, that is, all trade occurring between 1965 and 2010 for given bilateral pairs in five year increments, and Agricultural Trade, from 1980 to 2008 in four year increments. Both datasets are a combination of several sources: trade data is based on countries' reported import notifications to the United Nation's Commodity Trade Statistics (Comtrade). Distance, common border, language, land locked countries, colonial linkages, and island countries data is collected from *Centre d'Etudes Prospective et d'Informations Internationales*(CEPII) in which geo-distance dataset is developed by Mayer and Zignago (2006)[1]. WTO report 2011 World Bank's (WB) World Development Indicators (WDI) and the United National Accounts Main Aggregate Database includes data on GDPs[2].

Comtrade data uses Standard Industrial Trade Classification (SITC) product codes, from which the Agricultural trade flows was compiled. Bilateral import values are collected on a nominal basis due to inappropriate deflation of trade flows (Baldwin & Taglioni, 2006) which can be corrected using time-varying fixed effects, specification 1. Feenstra et al. (2005) mirrored trade flows are utilized when countries' imports are missing by using exporters' reported exports.

The WTO 2011 report provides information on whether the importers and exporters are in the WTO and what year they joined. Table 4.2 reports the predicted sign of the variables

[1]CEPII is an independent European research institute on the international economy stationed in Paris, France. It can be accessed at `www.cepii.com`

[2]We use GDP data from Penn World Tables (6.3) to supplement WB and UN data where there is incomplete or missing data. Development indicators are retrieved from `http://databank.worldbank.org/data/home.aspx`,a d UN GDP data can be retrieved from `http://unstats.un.org/unsd/snaama/dnllist.asp`. Lastly, Penn World Tables can be accessed at the Center for International Comparisons at the University of Pensilvania's website: `http://pwt.econ.upenn.edu/`.

based on previous studies, as well as the definitions for the variables used in our study. We hope to find that using BMA, our signs are similar to previous studies for distinct pluses and minuses, and yet we are better able to report the signs of those variables that are mixed from finding to finding by having an averaged result over all models.

The following figure provides further motivation for the study of the impact of WTO on trade flows for our world trade data compilation. We present in Figure 4.2 the number of countries that joined the WTO over time.

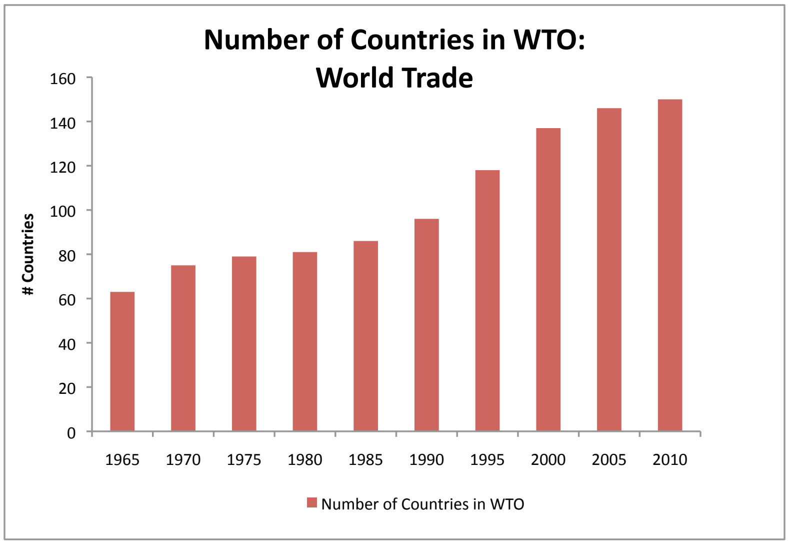



Figure 4.1: Number of countries in the WTO for world trade data

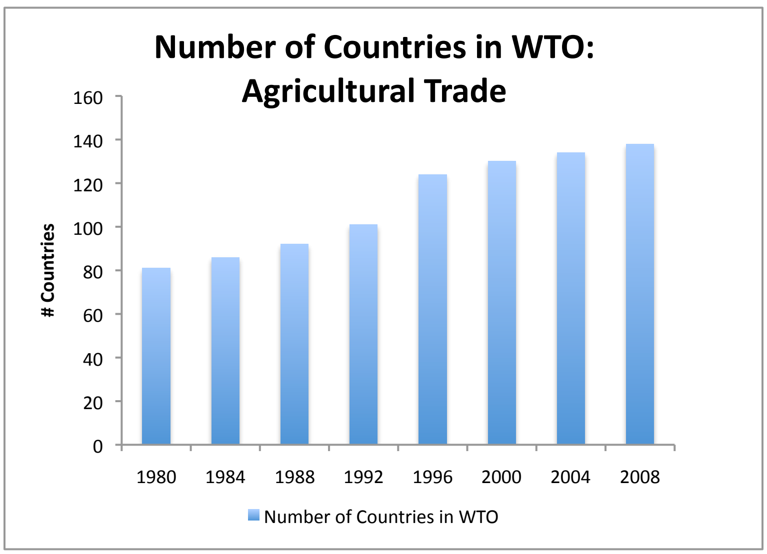



Figure 4.2: Number of countries in the WTO for agricultural trade data

We can tell from Figure 4.2, that over time the number of countries that joined the WTO increases, exhibiting the same pattern as the increase in trade flows over time. Thus the figures present motivation for researching the impact of a country being part of the WTO rather than a country that is not part of the WTO, given the number of countries that continue to join. Given this magnitude we hope to find that when the posterior inclusion probability is significant, that being a member of the WTO actually increases trade flows.

Table 4.2 presents all of the regressors included in our world trade and agricultural trade datasets, provided with description.

Table 4.2: Variable description

| | | based on past studies | Variable description |
|---|---|---|---|
| | | Sign | |
| **Core Gravity** | lgdpi | (+) | log of GDP of exporting ctry in Mil. |
| | lgdpj | (+) | log of GDP of importing ctry in Mil. |
| | ld | (-) | log of distance between ctrys (km) (weighted by important cities in terms of pop) |
| **Geography** | LandLockij | (+/-) | =1 if one is, and 2=if both are landlocked |
| | LandLocki | (+/-) | 1=if exporter is landlocked |
| | LandLockj | (+/-) | 1=if importer is landlocked |
| | Islandi | (+/-) | 1=if exporter is island nation |
| | Islandj | (+/-) | 1=if importer is isalnd nation |
| | Contigji | (+) | 1=if importer and exporter share land border |
| | Islandij | (+/-) | 0=if neither is island; =1 if one is, and =2 if both are island ctrys |
| **Historical Ties** | Langij | (+) | 1=if importer and exporter speak same language |
| | Colony | (+) | 1=if importer and exprter have ever had colonial relationship |
| | Comcolij | (+) | 1=if importer and exporter were colonized by same ctry |
| | Curcolij | (+/-) | 1=if importer and exproter are currently in a colonial relationship |
| | Col45 | (+) | 1=if importer and exporter have had a colonial relationship after 1945 |
| | Smctry | (+) | 1=if importer and exporter were ever the same country |
| **WTO** | Bothin | (+/-) | 1=if importer and exproter are WTO members in year t |
| | Onein | (+/-) | 1=if importer or exproter, (not both) are a WTO |

This table was compiled using Table 2 in Eicher, Henn & Papageorgiou (2012). The definitions were retrieved from Ghosh & Yamarik (2004)

"Historical Ties" encompass common language and colonial ties. These regressors are commonly added into the gravity equation to capture transaction costs (Wei, 1996; Frankel, 1997; Frankel & Rose, 2002; Soloaga & Winters, 2001; Rose & vanWincoop, 2001).

Next we look at "Geographic factors," which include *Remoteness*, further described in the theory and data sections. These came about to proxy for transportation costs (Aitken, 1973), trade and geography theories (Helpman, 1987), and new trade theories (Rivera & Romer, 1991). Other proxies include *Border*, *Landlocked*, and *Island* (Frankel & Romer, 1999; Feenstra et al., 2001; Frankel & Rose, 2002; Rose, 2000; Rose & vanWincoop, 2001; Soloaga & Winters, 2001).

Table 4.3: Summary statistics

| | World Trade (1965-2010) | | Agricultural Trade (1980-2008) | |
|---|---|---|---|---|
| | Observations | % of Total | Observations | % of Total |
| Total | 269,547 | | 179723 | |
| Positive Trade Flow | 194,993 | 72% | 130291 | 72% |
| Zero Trade Flow | 74,554 | 28% | 49432 | 28% |

We assume uniform prior over the model space, which is standard in the literature; see Raftery, et. al. (1997) and Fernandez et. al. (2001a). We perform the MCMC search algorithm using R under the Bayesian Model Simulation (BMS) package.

## 4.5 Results

The results are presented in three different sections. First we use the dataset of Rose (2004a), and apply BMA under the two specifications of time FE and country-pair and time FE. Then we continue with our own two compiled data sets of world trade and agricultural trade, again running BMA under the two specifications.

### 4.5.1 Rose Dataset Results

We first run the BMA approach for the Rose (2004a) dataset. The results are listed in Table 4.4.

Table 4.4: Rose (2004a) dataset

| | | **Time Fixed Effects** | | | | **Country-Pair and Time Fixed Effects** | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | PIP | Post Mean | Post SD | p(>0) | PIP | Post Mean | Post SD | p(>0) |
| **Core Gravity** | $lgdp_i$ | 1.000 | 1.089 | 0.004 | 1.000 | 1.000 | 1.219 | 0.012 | 1.000 |
| | $lgdp_j$ | 1.000 | 1.089 | 0.004 | 1.000 | 1.000 | 1.219 | 0.012 | 1.000 |
| | ld | 1.000 | -0.946 | 0.005 | 0.000 | | | | |
| **Geography** | $LandLock_{ij}$ | 1.000 | -0.686 | 0.01 | 0.000 | | | | |
| | $border_{ji}$ | 1.000 | 1.146 | 0.023 | 1.000 | | | | |
| | landap | 1.000 | 0.000 | 0.00 | 1.000 | | | | |
| | $Island_{ij}$ | 1.000 | -1.243 | 0.01 | 0.000 | | | | |
| **Historical Ties** | $comlang_{ij}$ | 0.003 | 0.005 | 0.00 | 1.000 | | | | |
| | Colony | 1.000 | 2.032 | 0.03 | 1.000 | | | | |
| | $Comctry_{ij}$ | 0.011 | 0.118 | 0.01 | 1.000 | | | | |
| | $Curcol_{ij}$ | 0.003 | 0.006 | 0.01 | 1.000 | | | | |
| | Col45 | 1.000 | 0.270 | 0.01 | 1.000 | | | | |
| | cpi | 1.000 | -0.053 | 0.00 | 0.000 | | | | |
| | custrict | 1.000 | 0.291 | 0.03 | 1.000 | | | | |
| | defp2 | 1.000 | 0.001 | 0.00 | 1.000 | | | | |
| | defp1 | 1.000 | 0.001 | 0.00 | 1.000 | | | | |
| **WTO** | gsp | 1.000 | 1.010 | 0.01 | 1.000 | 1.000 | 0.272 | 0.017 | 1.000 |
| | bothin | 1.000 | 1.201 | 0.01 | 1.000 | 1.000 | 0.359 | 0.040 | 1.000 |
| | onein | 1.000 | 0.511 | 0.01 | 1.000 | 1.000 | 0.075 | 0.030 | 1.000 |

The dependent variable is the natural logarithm of trade between two countries. "PIP" stands for posterior inclusion probabilities, "Post Mean" is the posterior mean, "Post SD" is the posterior standard deviation, and "$p(>0)$" stands for the proportion of the probability density to the right of zero.

In the table, "PIP" stands for posterior inclusion probabilities, "Post Mean" is the posterior mean, that is the model averaged posterior mean, "Post SD" is the posterior standard deviation, also the model averaged posterior standard deviation, and "$p(>0)$" stands for the proportion of the probability density to the right of zero. Since we are estimating both time fixed effects and country-pair and time fixed effects, both specifications have another

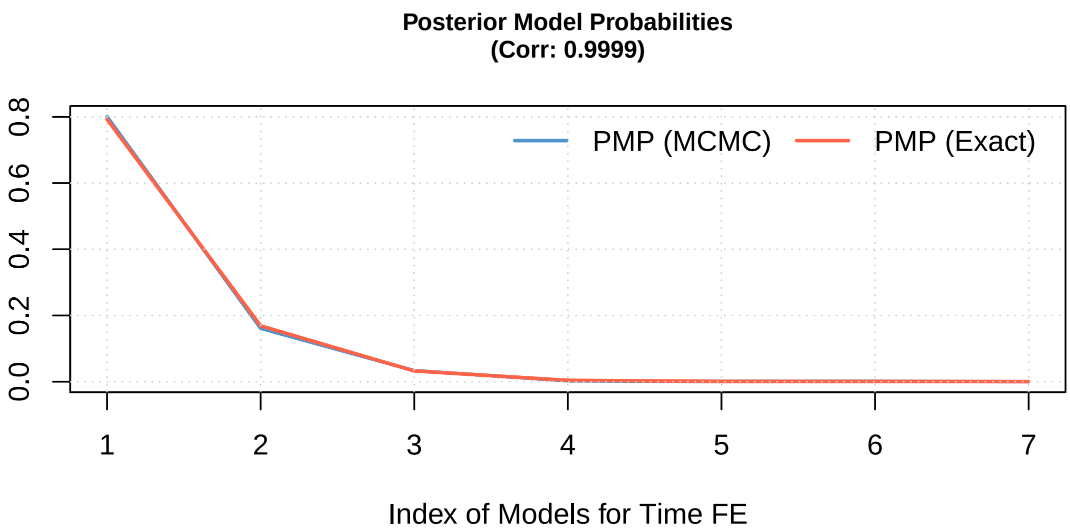
52 time-dummy regressors, since there are 53 distinct years.

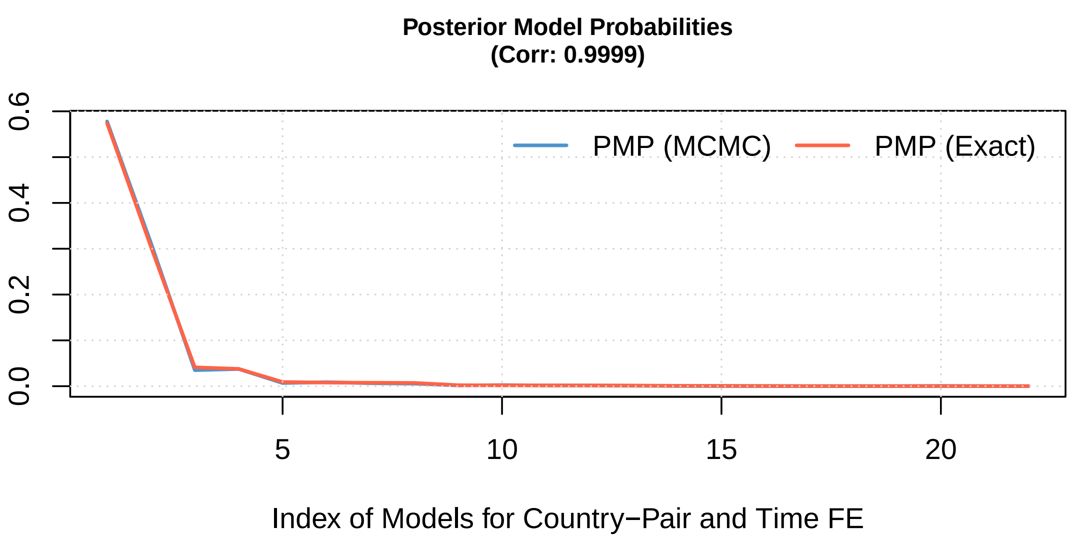
Under both time and country pair and time fixed effects, inclusion in the WTO increases trade flows. Under time fixed effects, the coefficients on *bothin* and *onein* – both countries are members of the WTO and one country is a member in the WTO, respectively – are positive and thus increase trade flows by a factor of about $(e^{1.201} - 1) * 100\% = 232\%$, a significant increase for *bothin* and $(e^{.511} - 1) * 100\% = 66\%$ for *onein*. Rose (2004a) also studied the Generalized System of Preferences (GSP), a formal system of exemptions from the WTO/GATT provided mostly to lower tariffs for the least developed countries without lowering tariffs for richer countries. In his default specification, which accounts for time-fixed effects, the coefficient is .86 (as listed under his Table 1 benchmark results), which is lower than ours but still consistent in that it significantly increases trade flows. However, ours is much lower for country-time fixed effects, standing at .272. Yet his results show that having one country in the WTO is $-.06$ for time fixed effects and .05 for country-pair and time fixed effects – both insignificant. However, under BMA, we find all three coefficients – *bothin*, *onein*, and *gsp* – are significant and positive under both specifications.

The BMA results derived from the Rose (2004a) dataset therefore contradict the results of Rose. This could be due to Rose not considering all possible models and not giving the correct weights to all the possible models. This is something BMA corrects for by examining all possible models and averaging over them.

Another regressor Rose chooses to use is *custrict* – a strict currency union, with a PIP of 1 and a positive increase for trade flows, not included in our dataset. He also uses land area, *landap*. While its PIP is at 100%, its posterior mean is at zero and would not change trade flows. He additionally considers the respective country populations *defp1* and *defp2*, which also do not change trade flows significantly. Lastly, he chooses to use a Consumer Price Index regressor *cpi*. This, once again, has a posterior inclusion probability of 1; however, it does not significantly change trade flows. We therefore omit these four regressors in our datasets, since they do not affect trade flows, but further dissect the regressors *island* and *LandLock* since our dataset has bilateral trade flows, and Rose averages over four possible combinations for two countries who trade: the positive import from country $j$ to country $i$ and vice-versa, and the positive export from country $i$ to country $j$ and vice-versa.

Figure 4.3: Rose results: posterior model probabilities convergence test



The plots in Figure 4.3 describe a formal convergence test of the analytical (labeled "Exact" in the plot) posterior model probabilities (PMPs) and the MCMC-empirical PMP, under both specifications. Fernandez et. al. (2001a) suggest comparing the empirical model probabilities to the analytical probabilities (based on marginal likelihoods). The correlation coefficient between these two sets of probabilities should be close to 1. Ours exhibit a correlation at over 99%, as seen in Figure 4.3, showing that the algorithm has converged. The first plot in Figure 4.3 is for time fixed effects; the second is for country-pair and time FE. Since the two sets of probabilities converge, our inference on our estimates, which was calculated via MCMC sampler, is accurate. That is, the two lines lie almost on top of each other.

We can also tell that the number of top models picked (Index of Models) for specification 2 (over 20) is much larger than the number of models picked for specification 1 (under 7). Thus there is much less controversy on which regressors are included and excluded for a particular model under specification 1.

In the next section, we use our own compiled datasets, with different year increments and slightly different regressors of *bothin* and *onein*, to measure the effect of membership in the WTO on trade flows.

### 4.5.2 World and Agricultural Trade

Next we provide BMA results, while adjusting for zero trade flow by adding 1 to each trade flows observation.

Table 4.5: Zero trade results–world trade

| | | **Time Fixed Effects** | | | | **Country-Pair and Time Fixed Effects** | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | PIP | Post Mean | Post SD | p(>0) | PIP | Post Mean | Post SD | p(>0) |
| **Core Gravity** | lgdp$_i$ | 1.000 | 1.531 | 0.005 | 1.00 | 1.000 | 0.855 | 0.017 | 1.00 |
| | lgdp$_j$ | 1.000 | 1.243 | 0.005 | 1.00 | 1.000 | 0.878 | 0.017 | 1.00 |
| | ld | 1.000 | -1.742 | 0.012 | 0.00 | | | | |
| **Geography** | LandLock$_{ij}$ | 1.000 | -0.817 | 0.033 | 0.00 | | | | |
| | LandLock$_i$ | 0.008 | 0.001 | 0.017 | 1.00 | | | | |
| | LandLock$_j$ | 0.996 | -0.267 | 0.039 | 0.00 | | | | |
| | Island$_i$ | 1.000 | 1.484 | 0.060 | 1.00 | | | | |
| | Island$_j$ | 1.000 | 1.223 | 0.060 | 1.00 | | | | |
| | Contig$_{ij}$ | 0.003 | 0.000 | 0.005 | 1.00 | | | | |
| | Island$_{ij}$ | 1.000 | -0.692 | 0.065 | 0.00 | | | | |
| **Historical Ties** | Lang$_{ij}$ | 1.000 | 0.892 | 0.028 | 1.00 | | | | |
| | Colony | 0.849 | 0.445 | 0.223 | 1.00 | | | | |
| | Comcol$_{ij}$ | 1.000 | 0.427 | 0.033 | 1.00 | | | | |
| | Curcol$_{ij}$ | 1.000 | -2.539 | 0.381 | 0.00 | | | | |
| | Col45 | 1.000 | 1.430 | 0.243 | 1.00 | | | | |
| | Smctry | 1.000 | 1.143 | 0.099 | 1.00 | | | | |
| **WTO** | Bothin | 1.000 | 2.061 | 0.032 | 1.00 | 1.000 | 2.085 | 0.053 | 1.00 |
| | Onein | 1.000 | 1.092 | 0.030 | 1.00 | 1.000 | 1.065 | 0.044 | 1.00 |

The dependent variable is the natural logarithm of trade (bilateral trade+1) to account for zero trade. "PIP" stands for posterior inclusion probabilities, "Post Mean" is the posterior mean, "Post SD" is the posterior standard deviation, and "$p(>0)$" stands for the proportion of the probability density to the right of zero.

Under both specifications there are another nine regressors not included in the results which are the time-dummies to account for time-fixed effects. Thus while the country-pair and time fixed effects only has four regressors in our output, there were actually $2^{13}$ possible models, and for time fixed effects there were $2^{(18+9+1)}$ possible models, that is 18 possible regressers presented in the output, 9 time dummies, and 1 *remoteness* variable.

We find that *bothin* is positive under both specifications; see Table 4.5, and has a high probability of being included in the model under both specifications. This finding confirms that membership in the GATT/WTO does increase trade flows, contrary to Rose (2004a), and does belong in the gravity model. This finding confirms WTO literature and the WTO's stance on liberalizing trade. Also, even when one partner is in the GATT/WTO that also increases trade flows. This implies there are benefits of increased trade flows from joining the WTO, even when the trading partner is not a member. However, trade flows are significantly larger when both members are in the WTO in world trade data.

When examining the other regressors of importance in the gravity equation, for time FE there are a total of fourteen regressors that should be included in the gravity model with a probability of 100% or all the time. This is a surprising finding since studies in international trade using the gravity model do not always include up to fourteen regressors in the model, and in cases of low numbers of observations, the results would lead to inefficient estimates. However, here under BMA we can efficiently estimate the coefficients on these fourteen regressors.

The core gravity regressors have theoretically sound results in which increases of GDPs for the importers and exporters will increase trade flows, and are consistent with previous research as presented in Table 4.1. Also log(*distance*) is also consistent with previous studies in that the larger the distance between two countries the less trade. For the geography regressors, the *LandLock* variables are consistent with intuition, that if two countries are land locked then they have fewer options of trading, since they do not have the option trading via bodies of water. Thus trade flows are much lower if both countries are land locked, and only slightly lower if the importer is land locked. However, the importer being land locked has a very low probability of inclusion in the model. All *island* coefficients have a probability of inclusion in the model of 100%, in which if either importer or exporter is an island then trade flows are increased, however, if both are islands than trade flows are actually decreased. *contiguity* is positive, consistent with previous results, Table 4.1, but under world trade has an inclusion probability of only .3%. Under the historical ties section, all regressors, except that of *Curcol* are positive, as shown under previous studies under Table 4.1. This is also intuitive, in that if two countries have a colonial relationship then they are less likely to trade since they might specialize in the same products.

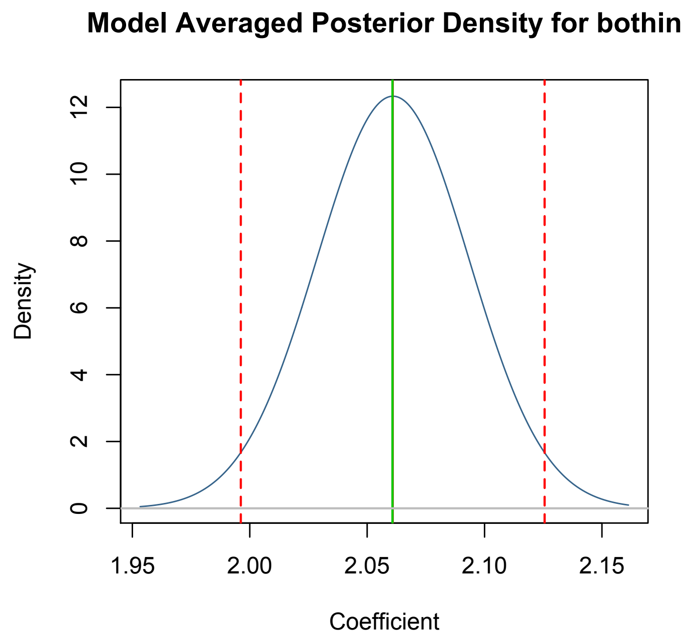



Figure 4.4: World trade marginal density, when both importer and exporter are in the WTO from time fixed effects estimation

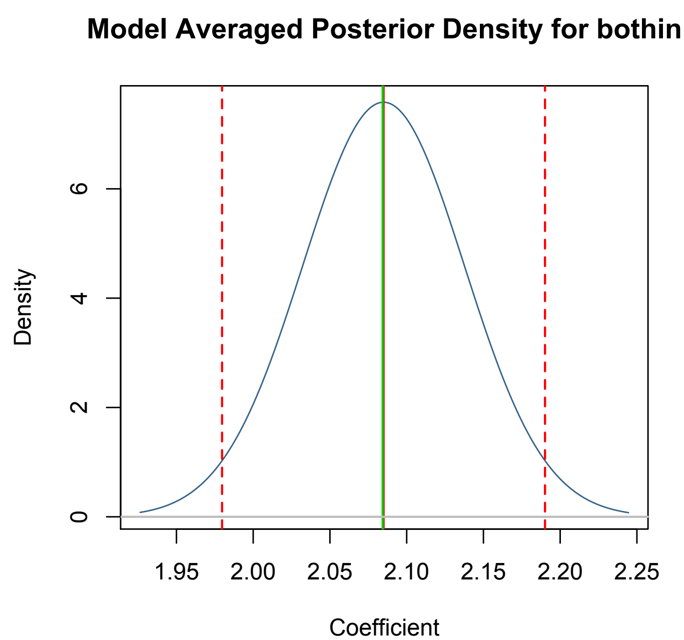



Figure 4.5: World trade marginal density, when both importer and exporter are in the WTO from country-pair and time fixed effects estimation

The green-solid line indicates the posterior mean for *bothin* and the red-dotted line indicates the confidence interval for *bothin*. The density of *bothin* for both specifications confirms that *bothin* is positive, with confidence bounds not including zero. Also, the coefficient posterior means are very close under both specifications, with the posterior mean for *bothin* under country-pair and time fixed effects slightly higher.

Next we continue with results for our compiled dataset for agricultural trade.

Table 4.6: Zero trade results-agricultural trade

| | | **Time Fixed Effects** | | | | **Country-Pair and Time Fixed Effects** | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | PIP | Post Mean | Post SD | p(>0) | PIP | Post Mean | Post SD | p(>0) |
| **Core Gravity** | $lgdp_i$ | 1.000 | 0.869 | 0.004 | 1.000 | 1.000 | 0.398 | 0.013 | 1.000 |
| | $lgdp_j$ | 1.000 | 0.765 | 0.004 | 1.000 | 1.000 | 0.454 | 0.013 | 1.000 |
| | ld | 1.000 | -1.111 | 0.011 | 0.000 | | | | |
| **Geography** | $LandLock_{ij}$ | 1.000 | -0.408 | 0.127 | 0.000 | | | | |
| | $LandLock_i$ | 0.948 | 0.282 | 0.117 | 0.999 | | | | |
| | $LandLock_j$ | 0.752 | -0.177 | 0.123 | 0.000 | | | | |
| | $Island_i$ | 1.000 | 0.706 | 0.045 | 1.000 | | | | |
| | $Island_j$ | 1.000 | 0.781 | 0.046 | 1.000 | | | | |
| | $Contig_{ij}$ | 1.000 | 0.294 | 0.053 | 1.000 | | | | |
| | $Island_{ij}$ | 1.000 | -0.559 | 0.050 | 0.000 | | | | |
| **Historical Ties** | $Lang_{ij}$ | 1.000 | 0.606 | 0.021 | 1.000 | | | | |
| | Colony | 1.000 | 1.353 | 0.091 | 1.000 | | | | |
| | $Comcol_{ij}$ | 1.000 | 0.173 | 0.026 | 1.000 | | | | |
| | $Curcol_{ij}$ | 0.739 | -0.749 | 0.502 | 1.000 | | | | |
| | Col45 | 1.000 | 0.959 | 0.117 | 1.000 | | | | |
| | Smctry | 1.000 | 0.538 | 0.073 | 1.000 | | | | |
| **WTO** | Bothin | 1.000 | 1.472 | 0.030 | 1.000 | 1.000 | 0.859 | 0.031 | 1.000 |
| | Onein | 1.000 | 0.817 | 0.030 | 1.000 | 1.000 | 0.701 | 0.026 | 1.000 |

The dependent variable is the natural logarithm of trade (bilateral trade+1) to account for zero trade. "PIP" stands for posterior inclusion probabilities, "Post Mean" is the posterior mean, "Post SD" is the posterior standard deviation, and "$p(>0)$" stands for the proportion of the probability density to the right of zero.

For agricultural trade there are only 8 distinct years, 1980-2008 in four year increments, thus now the county-pair fixed effects model has up to $2^{4+7}$ possible models, that is including 7 time-dummies, and the time fixed effects model has $2^{(18+7+1)}$ possible models, that is, also adding the *remoteness* variable.

When further examining the coefficients for agricultural trade, *bothin* is positive for both specifications, as in world trade, but smaller than under the world trade dataset. Thus membership in the GATT/WTO affects trade flows more in world trade than in agricultural trade, but contrary to Subramanian & Wei (2007), does indeed increase trade flows. Also, *onein* is also positive, indicating that in agricultural trade even if one partner in trade is a member of the GATT/WTO, trade flows will increase.

All of the coefficients under agricultural trade have a high inclusion probability with the lowest inclusion probability of 73% for *Curcol*. Thus when estimating just agricultural trade, there are more coefficients that contribute to trade flows in the gravity model, which once again most of the time are not all included when estimating the gravity equation in current literature. Unlike in world trade, the inclusion probability of *Landlock* for the exporting country is significantly higher, with a positive coefficient. Thus while *Landlock* for exporting country under world trade is also positive, its inclusion probability was very low, and thus not very likely to be included in the model. However, now since the PIP is at 94.8%, for agricultural trade, if the exporting country is land locked then trade flows will increase. Also, the probability that $Landlock_i$ is to the right of zero, that is positive, is slightly less than 100% of the time, as illustrated in the column, $p(>0)$. This is the only variable that does not have a 100% probability of either being above zero or below zero.

Another coefficient of interest is *Contig*, if importer and exporter share a land border. While for world trade its inclusion probability was very small, for agricultural trade is at 100%. Thus *Contig* plays a bigger role in increasing trade flows for agricultural trade versus world trade.

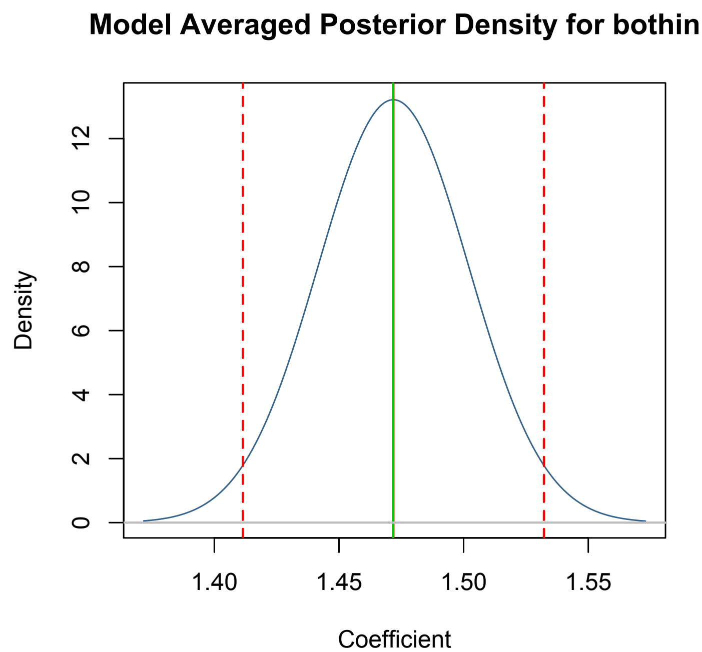



Figure 4.6: Agricultural trade marginal density, corrected for zero trade, when both importer and exporter are in the WTO from time fixed effects estimation

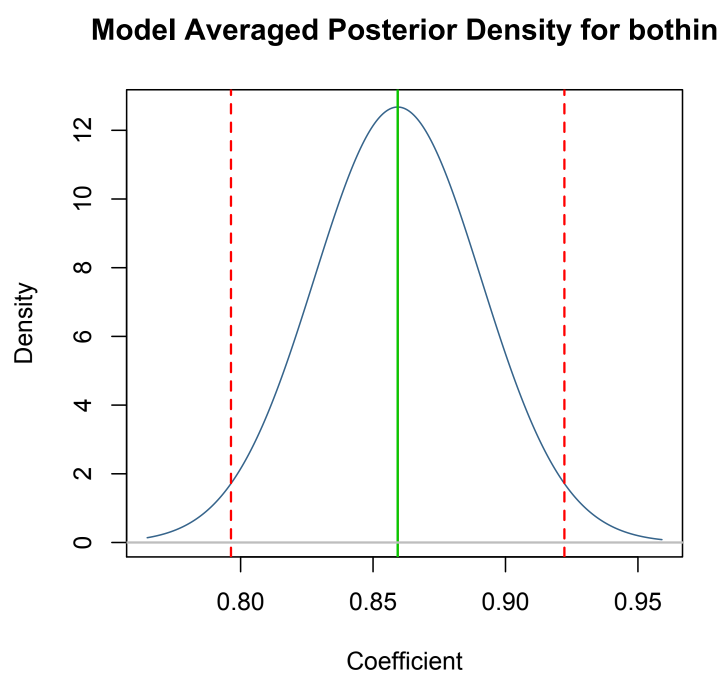
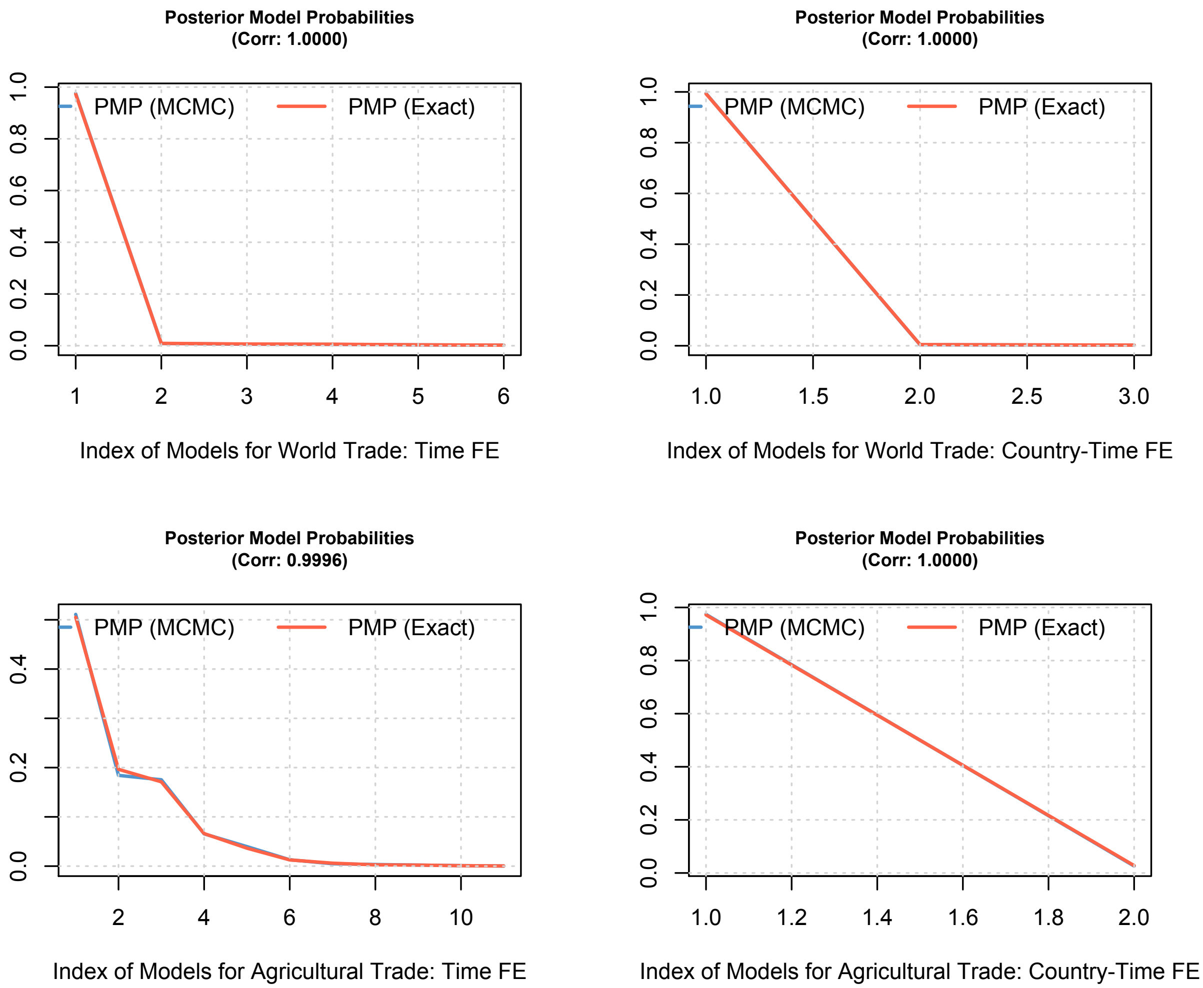



Figure 4.7: Agricultural trade marginal density, corrected for zero trade, when both importer and exporter are in the WTO from country-pair and time fixed effects estimation

Once again, the solid line indicates the posterior mean for *bothin* and the red-dotted line indicates the confidence interval for *bothin*.The confidence intervals under both specifications are above zero, once again indicating the probability that *bothin* is positive is 100%, also shown in Table 4.6, under column $p(>0)$. Under agricultural trade, however, the difference in posterior means for *bothin* has a much larger change from specification 1 to specification 2. Under time FE the posterior mean is much larger than that of country-pair and time FE. Thus once again showing that in agricultural trade, there is much more volatility in the coefficient. However, it is conclusively positive.

Figure 4.8: PMP convergence




Formal convergence test of the analytical (labeled Exact in the plot) posterior model probabilities (PMP) and the MCMC-empirical PMP, under both specifications is performed once again. The correlation coefficient between these two sets of probabilities should be close to 1, ours above exhibit a correlation at over 99% in Figure 4.8, for all four plots, showing that the algorithm has converged.

The number of models considered for both datasets shows that under country-pair and time fixed effects specification is at most 2 (indicated in the right-bottom corner). This is relevant since there were fewer regressors considered for this specification. Also for agricultural trade, there are a lot more models considered than under world trade for time fixed effects specification. This is also interesting since there has been more controversy over membership in GATT/WTO in agricultural trade versus world trade (Grant & Boys, 2012; Subramanian & Wei, 2007). However, BMA has considered all such models when estimating its averaged results.

We have shown that membership in the WTO significantly increases trade flows, showing that not only *bothin*, but *onein*, regressors have a probability of inclusion in the model at 100% and increase trade flows.

## 4.6 Conclusion

Due to the lack of univocal consensus of the effect of membership in the GATT/ WTO on trade flows, as first presented by Rose (2004a), we were able to use BMA and show that both *bothin* and *onein* increase trade flows. We were able to confirm that in both world trade and agricultural trade, membership in the WTO increases trade flows, contrary to Subramanian & Wei (2007) but in accordance with Grant & Boys (2012). We actually found that *bothin* and *onein* have inclusion probabilities of 100%, and thus affect trade flows in the gravity model.

We were also able to use Rose (2004a) data, and there, too, we found that membership in the WTO increases trade flows. BMA allowed us to study the uncertainty in the WTO literature by looking at all possible regressors in the gravity model, and we were able to conclude that membership in the WTO does in fact increase trade flows.

We were also able to study another 16 regressors commonly used when estimating the gravity model, and found that under world trade data, 16 regressors have an inclusion probability of over 50%; for agricultural trade, all regressors do. Most importantly, the three canonical regressors of $\log(gdp_i)$, $\log(gdp_j)$, and $\log(dist_{ij})$ always have an inclusion probability of 100% in all of our results. This shows that BMA is a good estimation technique in the following precise sense: it preserves the gravity model and provides inference in the presence of theoretical uncertainty. This paves the way for further research in areas of uncertainty obtained when using the gravity model.

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# CHAPTER 5

# CONCLUSION

I conclude by summarizing the main findings of all three essays.

The first essay estimates the demand for natural gas as an alternative fuel for diesel with an underlying preference function that describes firms' willingness to pay for CNG. Using EIA data, results show that an increase in the price of diesel by $.10, or a decrease in the price of natural gas by $.10, will increase firms' consumption of CNG by 5.59%. The results also showed that an increase in CNG infrastructure – in particular, CNG stations – will increase demand.

Using the regression results, the market share for CNG was constructed, and mu's were calibrated. For the available data, we find that for each year $\mu > 0$, indicating that the indirect costs for CNG exceed those of DF almost all the time. The probability that the indirect costs of using CNG exceeded those of using DF for firms in 2009 was .9987 – almost all the time. This is a reasonable finding given the lack of existing infrastructure for CNG and lack of information about NGVs.

Lastly, using regression findings, policy implications dealing with new technological advancements in drilling for natural gas – in particular, horizontal drilling and its unique ability to tap the vast natural gas resources in Marcellus Shale(s) – were analyzed. We consider two relevant policy scenarios. In the first scenario, the increase in supply reduced prices for CNG, increasing the equilibrium demand for total CNG of firms with hybrid fleets. In the second, an increase in supply induced exportation, driving the prices of CNG up, yet still increasing the demand for total CNG of these firms.

For the second essay, the effects of RTAs on total merchandise and agricultural trade were estimated by decomposing them based on which policy areas they include. The focus was on two policy areas: SPS and TBT safety measures. Findings show that SPS, in particular, increases trade flow for both datasets more than TBT. More precisely, agricultural trade flows increase by 101% if an RTA includes SPS, TBT and any of the other 12 topics. If, however, an RTA does not include SPS but includes TBT and any of the other 12 topics, it would cause only a 24% increase in agricultural trade flows. Thus, RTAs that include SPS safety measures under their agreement would increase their trade flows for agricultural goods. SPS also impacts world trade, but to a lesser extent; that is, RTAs with SPS, TBT, and any of the other 12 topics increase trade flows for world trade by 69%. Thus the overall effect of RTAs on world trade flows is much less than in agricultural trade, since an RTA that does not include any of the topics actually decreases trade flows by 123%.

Lastly, in agricultural trade, RTAs that include SPS have a clear advantage over RTAs that do not. Since SPS safety measures affect agricultural goods, we conclude that to study the importance of these policy areas in RTAs, we must decompose world trade into correct subsets (agriculture, manufacturing, etc.) and analyze the particular policy areas that affect those subsets. This can be extended to further research. For example, the study of countervailing measures and antidumping can be extended to manufacturing trade, since both measures deal with undercutting the cost of production.

Nonetheless, we conclude that once RTAs are decomposed into policy areas and the appropriate policy areas are tested for (SPS in our case), RTAs that cover those policy areas make a substantial contribution to trade flows. We also conclude that not all RTAs have the same effect on trade flows, since RTAs in agricultural trade that do have SPS increase trade flows more than those that do not. On a larger scale, RTAs that cover at least one of the other twelve policy areas examined in this study increase trade flows by more than those RTAs that cover no policy areas. Thus, not all RTAs are equal, and not all will affect trade flows equally.

Lastly, the third essay addresses theoretical gaps in the WTO literature first identified by Rose (2004a). It used BMA to show that both *bothin* and *onein* increase trade flows when both endogeneity due heterogeneity and zero trade are corrected for. The study confirmed that in both world trade and agricultural trade, membership in the WTO increases trade flows, contrary to Subramanian & Wei (2007) but in accordance with Grant & Boys (2012). Results showed that the increase in trade flows is significant in both datasets. The Data by Rose (2004a) was used, and there, too, results showed that membership in the WTO increases trade flows. The use of BMA allowed us to study the uncertainty in the WTO literature by looking at all possible regressors in the gravity model. We concluded that membership in the WTO does in fact increase trade flows.

In this third essay, another sixteen regressors commonly used when estimating the gravity model were examined. The study found that under world trade data, fourteen regressors are always included; for agricultural trade, all regressors are included in all/most models under zero trade correction. Most importantly, the three canonical (theoretically consistent) regressors of $\log(gdp_i)$, $\log(gdp_j)$, and $\log(dist_{ij})$ are always included in all results. This shows that BMA is a useful estimation technique in the following precise sense: it generalizes the gravity model by providing inference on policies such as WTO membership in the presence of theoretical uncertainty. This paves the way for further research in areas of model and specification uncertainty obtained when using the gravity model.

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# APPENDIX A

# APPENDIX: SOLVING FOR $\mu$

We solve for $\mu$ using equation (2.7), then we can solve for $\hat{\mu}$ for each year as follows:

$$\mu_t = \theta_{it} - \gamma \ln(2H(\theta_{it}))$$
$$\hat{\mu} = \bar{p_t} - \hat{\gamma} \ln(2H(\theta_{it}))$$

where $H(\theta_{it})$ is defined and calibrated in footnote 6, $\hat{\gamma} = 1/\hat{\beta}$, and $\bar{p_{it}}$ is the averaged price premium in year $t$ over the 47 states. We are able to retrieve fourteen mus out of twenty-one because of missing data for the number of NGVs.

# APPENDIX B

## APPENDIX: CALIBRATED DEMAND

We estimate $\hat{\ln Q_t}$ using (2.5), (2.8), and (2.9), i.e.:

$$\begin{aligned} \hat{\ln Q_t} &= \alpha + \beta_1(-p_t) + \beta_2 \ln(stations) \\ &= 10.663 + .559(-p_t) + .656 \ln(stations) \end{aligned}$$

The values of 11.17, .394 and .565 come from our 2SLS estimations. Then for $-(p_t)$ we pick reasonable price premiums for California, we pick twenty points, and thus have a vector of twenty points for $\hat{\ln Q_t}$, and our demand function.

APPENDIX C

# APPENDIX: LIST OF RTAS

All bolded RTAs are included in our datasets.

**WTO's Database of RTAs**

| Count | RTA NAME | YEAR NOTIFIED | YEAR ENTERED INTO FORCE | RTA TYPE | CU | FTA | PSA |
|---|---|---|---|---|---|---|---|
| **1** | **EU6** | **1958** | **1958** | **CU** | **1** | **0** | **0** |
| 2 | EFTA | 1960 | 1960 | FTA | 0 | 1 | 0 |
| 3 | CACM | 1961 | 1961 | CU | 1 | 0 | 0 |
| 4 | EFTAISL | 1970 | 1970 | FTA | 0 | 1 | 0 |
| **5** | **SACU** | **2004** | **1970** | **CU** | **1** | **0** | **0** |
| **6** | **EU-OCT** | **1971** | **1971** | **FTA** | **0** | **1** | **0** |
| **7** | **EU9** | **1973** | **1973** | **CU** | **1** | **0** | **0** |
| **8** | **EUCHE** | **1973** | **1973** | **FTA** | **0** | **1** | **0** |
| **9** | **EUISL** | **1973** | **1973** | **FTA** | **0** | **1** | **0** |
| **10** | **EUNOR** | **1973** | **1973** | **FTA** | **0** | **1** | **0** |
| 11 | PTN | 1973 | 1973 | PSA | 0 | 0 | 1 |

**WTO's Database of RTAs**

| Count | RTA NAME | YEAR NOTIFIED | YEAR ENTERED INTO FORCE | RTA TYPE | CU | FTA | PSA |
|---|---|---|---|---|---|---|---|
| 12 | CARICOM | 1975 | 1973 | CU | 1 | 0 | 0 |
| **13** | **APTA** | **1976** | **1976** | **PSA** | **0** | **0** | **1** |
| **14** | **EUSYR** | **1977** | **1977** | **FTA** | **0** | **1** | **0** |
| 15 | PATCRA | 1977 | 1977 | FTA | 0 | 1 | 0 |
| **16** | **EU10** | **1981** | **1981** | **CU** | **1** | **0** | **0** |
| 17 | SPARTECA | 1981 | 1981 | PSA | 0 | 0 | 1 |
| 18 | LAIA | 1983 | 1981 | PSA | 0 | 0 | 1 |
| **19** | **AUSNZL** | **1983** | **1983** | **FTA** | **0** | **1** | **0** |
| **20** | **USAISR** | **1985** | **1985** | **FTA** | **0** | **1** | **0** |
| **20** | **EU12** | **1986** | **1986** | **CU** | **1** | **0** | **0** |
| **21** | **ANDEAN** | **1991** | **1988** | **CU** | **1** | **0** | **0** |
| 22 | CUSTA | 1989 | 1989 | FTA | 0 | 1 | 0 |
| 23 | GSTP | 1989 | 1989 | PSA | 0 | 0 | 1 |
| 24 | LAOTHA | 1991 | 1991 | PSA | 0 | 0 | 1 |
| **25** | **MERC** | **1991** | **1991** | **CU** | **1** | **0** | **0** |
| 26 | EUAND | 1999 | 1991 | CU | 1 | 0 | 0 |
| **27** | **ASEAN** | **1992** | **1992** | **FTA** | **0** | **1** | **0** |
| 28 | ECO | 1992 | 1992 | PSA | 0 | 0 | 1 |
| **29** | **EFTATUR** | **1992** | **1992** | **FTA** | **0** | **1** | **0** |
| **30** | **CEFTA** | **2005** | **1992** | **FTA** | **0** | **1** | **0** |
| **31** | **EFTAISR** | **1993** | **1993** | **FTA** | **0** | **1** | **0** |
| 32 | FRONOR | 1997 | 1993 | FTA | 0 | 1 | 0 |
| 33 | KGZRUS | 2000 | 1993 | FTA | 0 | 1 | 0 |
| 34 | ARMRUS | 2005 | 1993 | FTA | 0 | 1 | 0 |

**WTO's Database of RTAs**

| Count | RTA NAME | YEAR NOTIFIED | YEAR ENTERED INTO FORCE | RTA TYPE | CU | FTA | PSA |
|---|---|---|---|---|---|---|---|
| **35** | **ECOWAS** | **2005** | **1993** | **CU** | **1** | **0** | **0** |
| **36** | **COMESA** | **1994** | **1994** | **FTA** | **0** | **1** | **0** |
| **37** | **NAFTA** | **1994** | **1994** | **FTA** | **0** | **1** | **0** |
| **38** | **CIS** | **2000** | **1994** | **FTA** | **0** | **1** | **0** |
| 39 | MSG | 2000 | 1994 | PSA | 0 | 0 | 1 |
| 40 | GEORUS | 2001 | 1994 | FTA | 0 | 1 | 0 |
| **41** | **UKRRUS** | **2008** | **1994** | **FTA** | **0** | **1** | **0** |
| **42** | **EU15** | **1995** | **1995** | **CU** | **1** | **0** | **0** |
| 43 | FROCHE | 1995 | 1995 | FTA | 0 | 1 | 0 |
| 44 | SAPTA | 1998 | 1995 | PSA | 0 | 0 | 1 |
| 45 | KGZKAZ | 2000 | 1995 | FTA | 0 | 1 | 0 |
| 56 | KGZARM | 2001 | 1995 | FTA | 0 | 1 | 0 |
| 47 | ARMMDA | 2004 | 1995 | FTA | 0 | 1 | 0 |
| 48 | CRIMEX | 2006 | 1995 | FTA | 0 | 1 | 0 |
| 49 | UKRTKM | 2008 | 1995 | FTA | 0 | 1 | 0 |
| **50** | **CHLMERC** | **1996** | **1996** | **PSA** | **0** | **0** | **1** |
| **51** | **EUTUR** | **1996** | **1996** | **CU** | **1** | **0** | **0** |
| 52 | KGZMDA | 2000 | 1996 | FTA | 0 | 1 | 0 |
| 53 | GEOAZE | 2001 | 1996 | FTA | 0 | 1 | 0 |
| 54 | GEOUKR | 2001 | 1996 | FTA | 0 | 1 | 0 |
| 55 | ARMTKM | 2004 | 1996 | FTA | 0 | 1 | 0 |
| 56 | ARMUKR | 2005 | 1996 | FTA | 0 | 1 | 0 |
| 57 | UKRAZE | 2008 | 1996 | FTA | 0 | 1 | 0 |
| 58 | UKRUZB | 2008 | 1996 | FTA | 0 | 1 | 0 |

**WTO's Database of RTAs**

| Count | RTA NAME | YEAR NOTIFIED | YEAR ENTERED INTO FORCE | RTA TYPE | CU | FTA | PSA |
|---|---|---|---|---|---|---|---|
| **59** | **CANCHL** | **1997** | **1997** | **FTA** | **0** | **1** | **0** |
| 60 | CANISR | 1997 | 1997 | FTA | 0 | 1 | 0 |
| **61** | **EUFRO** | **1997** | **1997** | **FTA** | **0** | **1** | **0** |
| **62** | **EUPSE** | **1997** | **1997** | **FTA** | **0** | **1** | **0** |
| **63** | **TURISR** | **1997** | **1997** | **FTA** | **0** | **1** | **0** |
| **64** | **EAEC** | **2000** | **1997** | **CU** | **1** | **0** | **0** |
| **65** | **EUTUN** | **1998** | **1998** | **FTA** | **0** | **1** | **0** |
| 66 | KGZUKR | 2000 | 1998 | FTA | 0 | 1 | 0 |
| 67 | KGZUZB | 2000 | 1998 | FTA | 0 | 1 | 0 |
| 68 | GEOARM | 2001 | 1998 | FTA | 0 | 1 | 0 |
| 69 | MEXNIC | 2005 | 1998 | FTA | 0 | 1 | 0 |
| 70 | PANARAB | 2007 | 1998 | FTA | 0 | 1 | 0 |
| 71 | UKRKAZ | 2008 | 1998 | FTA | 0 | 1 | 0 |
| 72 | CEMAC | 1999 | 1999 | CU | 1 | 0 | 0 |
| 73 | EFTAMAR | 1999 | 1999 | FTA | 0 | 1 | 0 |
| 74 | EFTAPSE | 1999 | 1999 | FTA | 0 | 1 | 0 |
| **75** | **CHLMEX** | **2002** | **1999** | **FTA** | **0** | **1** | **0** |
| 76 | GEOKAZ | 2002 | 1999 | FTA | 0 | 1 | 0 |
| 77 | EAC | 2000 | 2000 | CU | 1 | 0 | 0 |
| **78** | **EUISR** | **2000** | **2000** | **FTA** | **0** | **1** | **0** |
| **79** | **EUMAR** | **2000** | **2000** | **FTA** | **0** | **1** | **0** |
| **80** | **EUMEX** | **2000** | **2000** | **FTA** | **0** | **1** | **0** |
| **81** | **EUZAF** | **2000** | **2000** | **FTA** | **0** | **1** | **0** |
| 82 | ISRMEX | 2000 | 2000 | FTA | 0 | 1 | 0 |

**WTO's Database of RTAs**

| Count | RTA NAME | YEAR NOTIFIED | YEAR ENTERED INTO FORCE | RTA TYPE | CU | FTA | PSA |
|---|---|---|---|---|---|---|---|
| 83 | WAEMU/UEMOA | 2000 | 2000 | CU | 1 | 0 | 0 |
| 84 | GEOTKM | 2001 | 2000 | FTA | 0 | 1 | 0 |
| **85** | **TURMKD** | **2001** | **2000** | **FTA** | **0** | **1** | **0** |
| **86** | **SADC** | **2005** | **2000** | **FTA** | **0** | **1** | **0** |
| 87 | EFTAMEX | 2001 | 2001 | FTA | 0 | 1 | 0 |
| 88 | EFTAMKD | 2001 | 2001 | FTA | 0 | 1 | 0 |
| **89** | **EUMKD** | **2001** | **2001** | **FTA** | **0** | **1** | **0** |
| 90 | NZLSGP | 2001 | 2001 | FTA | 0 | 1 | 0 |
| **91** | **USAJOR** | **2001** | **2001** | **FTA** | **0** | **1** | **0** |
| 92 | INDLKA | 2003 | 2001 | FTA | 0 | 1 | 0 |
| 93 | ARMKAZ | 2005 | 2001 | FTA | 0 | 1 | 0 |
| 94 | MEXGTM | 2006 | 2001 | FTA | 0 | 1 | 0 |
| 95 | MEXHND | 2006 | 2001 | FTA | 0 | 1 | 0 |
| 96 | MEXSLV | 2006 | 2001 | FTA | 0 | 1 | 0 |
| 97 | UKRMKD | 2008 | 2001 | FTA | 0 | 1 | 0 |
| **98** | **CHLCNA** | **1999** | **2002** | **FTA** | **0** | **1** | **0** |
| 99 | CANCRI | 2002 | 2002 | FTA | 0 | 1 | 0 |
| 100 | CHLCRI | 2002 | 2002 | FTA | 0 | 1 | 0 |
| 101 | EFTAHRV | 2002 | 2002 | FTA | 0 | 1 | 0 |
| 102 | EFTAJOR | 2002 | 2002 | FTA | 0 | 1 | 0 |
| **103** | **EUJOR** | **2002** | **2002** | **FTA** | **0** | **1** | **0** |
| **104** | **JPNSGP** | **2002** | **2002** | **FTA** | **0** | **1** | **0** |
| 105 | CHLSLV | 2004 | 2002 | FTA | 0 | 1 | 0 |
| 106 | APTA-CHN | 2005 | 2002 | PSA | 0 | 0 | 1 |

**WTO's Database of RTAs**

| Count | RTA NAME | YEAR NOTIFIED | YEAR ENTERED INTO FORCE | RTA TYPE | CU | FTA | PSA |
|---|---|---|---|---|---|---|---|
| **107** | **EUHRV** | **2005** | **2002** | **FTA** | **0** | **1** | **0** |
| 108 | UKRTJK | 2008 | 2002 | FTA | 0 | 1 | 0 |
| **109** | **EUSMR** | **2010** | **2002** | **CU** | **1** | **0** | **0** |
| 110 | CEFTA-HRV | 2003 | 2003 | FTA | 0 | 1 | 0 |
| 111 | EFTASGP | 2003 | 2003 | FTA | 0 | 1 | 0 |
| **112** | **EUCHL** | **2003** | **2003** | **FTA** | **0** | **1** | **0** |
| **113** | **EULBN** | **2003** | **2003** | **FTA** | **0** | **1** | **0** |
| **114** | **SGPAUS** | **2003** | **2003** | **FTA** | **0** | **1** | **0** |
| **115** | **TURBIH** | **2003** | **2003** | **FTA** | **0** | **1** | **0** |
| **116** | **TURHRV** | **2003** | **2003** | **FTA** | **0** | **1** | **0** |
| **117** | **GCC** | **2005** | **2003** | **CU** | **1** | **0** | **0** |
| 118 | PANSLV | 2005 | 2003 | FTA | 0 | 1 | 0 |
| 119 | PICTA | 2008 | 2003 | FTA | 0 | 1 | 0 |
| 120 | INDAFG | 2010 | 2003 | PSA | 0 | 0 | 1 |
| **121** | **CHNHKG** | **2004** | **2004** | **FTA** | **0** | **1** | **0** |
| **122** | **CHNMAC** | **2004** | **2004** | **FTA** | **0** | **1** | **0** |
| **123** | **EFTACHL** | **2004** | **2004** | **FTA** | **0** | **1** | **0** |
| **124** | **EU25** | **2004** | **2004** | **CU** | **1** | **0** | **0** |
| **125** | **EUEGY** | **2004** | **2004** | **FTA** | **0** | **1** | **0** |
| **126** | **KORCHL** | **2004** | **2004** | **FTA** | **0** | **1** | **0** |
| **127** | **USACHL** | **2004** | **2004** | **FTA** | **0** | **1** | **0** |
| **128** | **USASGP** | **2004** | **2004** | **FTA** | **0** | **1** | **0** |
| 129 | CEZ | 2008 | 2004 | FTA | 0 | 1 | 0 |
| 130 | PANTWN | 2010 | 2004 | FTA | 0 | 1 | 0 |

**WTO's Database of RTAs**

| Count | RTA NAME | YEAR NOTIFIED | YEAR ENTERED INTO FORCE | RTA TYPE | CU | FTA | PSA |
|---|---|---|---|---|---|---|---|
| **131** | **ASEANCHN** | **2005** | **2005** | **PSA** | **0** | **0** | **1** |
| 132 | EFTATUN | 2005 | 2005 | FTA | 0 | 1 | 0 |
| **133** | **JPNMEX** | **2005** | **2005** | **FTA** | **0** | **1** | **0** |
| **134** | **THAAUS** | **2005** | **2005** | **FTA** | **0** | **1** | **0** |
| 135 | THANZL | 2005 | 2005 | FTA | 0 | 1 | 0 |
| **136** | **TURPSE** | **2005** | **2005** | **FTA** | **0** | **1** | **0** |
| **137** | **TURTUN** | **2005** | **2005** | **FTA** | **0** | **1** | **0** |
| **138** | **USAAUS** | **2005** | **2005** | **FTA** | **0** | **1** | **0** |
| **139** | **EUDZA** | **2006** | **2005** | **FTA** | **0** | **1** | **0** |
| 140 | JORSGP | 2007 | 2005 | FTA | 0 | 1 | 0 |
| **141** | **INDSGP** | **2008** | **2005** | **FTA** | **0** | **1** | **0** |
| **142** | **PAKLKA** | **2008** | **2005** | **FTA** | **0** | **1** | **0** |
| 143 | UKRMDA | 2008 | 2005 | FTA | 0 | 1 | 0 |
| **144** | **CAFTA-DR** | **2006** | **2006** | **FTA** | **0** | **1** | **0** |
| **145** | **CHLCHN** | **2006** | **2006** | **FTA** | **0** | **1** | **0** |
| **146** | **EFTAKOR** | **2006** | **2006** | **FTA** | **0** | **1** | **0** |
| **147** | **EUALB** | **2006** | **2006** | **FTA** | **0** | **1** | **0** |
| **148** | **JPNMYS** | **2006** | **2006** | **FTA** | **0** | **1** | **0** |
| 149 | KORSGP | 2006 | 2006 | FTA | 0 | 1 | 0 |
| **150** | **TURMAR** | **2006** | **2006** | **FTA** | **0** | **1** | **0** |
| **151** | **USABHR** | **2006** | **2006** | **FTA** | **0** | **1** | **0** |
| **152** | **USAMAR** | **2006** | **2006** | **FTA** | **0** | **1** | **0** |
| 153 | PANSGP | 2007 | 2006 | FTA | 0 | 1 | 0 |
| 154 | ISLFRO | 2008 | 2006 | FTA | 0 | 1 | 0 |

**WTO's Database of RTAs**

| Count | RTA NAME | YEAR NOTIFIED | YEAR ENTERED INTO FORCE | RTA TYPE | CU | FTA | PSA |
|---|---|---|---|---|---|---|---|
| **155** | **SAFTA** | **2008** | **2006** | **FTA** | **0** | **1** | **0** |
| 156 | TPSEP | 2008 | 2006 | FTA | 0 | 1 | 0 |
| 157 | UKRBLR | 2008 | 2006 | FTA | 0 | 1 | 0 |
| 158 | INDBTN | 2009 | 2006 | FTA | 0 | 1 | 0 |
| **159** | **CHLJPN** | **2007** | **2007** | **FTA** | **0** | **1** | **0** |
| 160 | EFTAEGY | 2007 | 2007 | FTA | 0 | 1 | 0 |
| 161 | EGYTUR | 2007 | 2007 | FTA | 0 | 1 | 0 |
| **162** | **EU27** | **2007** | **2007** | **CU** | **1** | **0** | **0** |
| **163** | **JPNTHA** | **2007** | **2007** | **FTA** | **0** | **1** | **0** |
| **164** | **TURSYR** | **2007** | **2007** | **FTA** | **0** | **1** | **0** |
| **165** | **PAKCHN** | **2008** | **2007** | **FTA** | **0** | **1** | **0** |
| **166** | **CHLIND** | **2009** | **2007** | **PSA** | **0** | **0** | **1** |
| **167** | **ASEANJPN** | **2008** | **2008** | **FTA** | **0** | **1** | **0** |
| **168** | **CHNNZL** | **2008** | **2008** | **FTA** | **0** | **1** | **0** |
| 169 | ECBIH | 2008 | 2008 | FTA | 0 | 1 | 0 |
| **170** | **ECCARIF** | **2008** | **2008** | **FTA** | **0** | **1** | **0** |
| 171 | EFTASACU | 2008 | 2008 | FTA | 0 | 1 | 0 |
| **172** | **JPNBRN** | **2008** | **2008** | **FTA** | **0** | **1** | **0** |
| **173** | **JPNIDN** | **2008** | **2008** | **FTA** | **0** | **1** | **0** |
| **174** | **JPNPHL** | **2008** | **2008** | **FTA** | **0** | **1** | **0** |
| **175** | **PAKMYS** | **2008** | **2008** | **FTA** | **0** | **1** | **0** |
| **176** | **PANCHL** | **2008** | **2008** | **FTA** | **0** | **1** | **0** |
| 177 | PANCRI | 2008 | 2008 | FTA | 0 | 1 | 0 |
| **178** | **TURALB** | **2008** | **2008** | **FTA** | **0** | **1** | **0** |

**WTO's Database of RTAs**

| Count | RTA NAME | YEAR NOTIFIED | YEAR ENTERED INTO FORCE | RTA TYPE | CU | FTA | PSA |
|---|---|---|---|---|---|---|---|
| **179** | **TURGEO** | **2008** | **2008** | **FTA** | **0** | **1** | **0** |
| 180 | NICTWN | 2009 | 2008 | FTA | 0 | 1 | 0 |
| 181 | HNDTWN | 2010 | 2008 | FTA | 0 | 1 | 0 |
| 182 | SLVTWN | 2010 | 2008 | FTA | 0 | 1 | 0 |
| **183** | **AUSCHL** | **2009** | **2009** | **FTA** | **0** | **1** | **0** |
| **184** | **CANPER** | **2009** | **2009** | **FTA** | **0** | **1** | **0** |
| **185** | **CHLCOL** | **2009** | **2009** | **FTA** | **0** | **1** | **0** |
| 186 | CHNSGP | 2009 | 2009 | FTA | 0 | 1 | 0 |
| **187** | **EFTACAN** | **2009** | **2009** | **FTA** | **0** | **1** | **0** |
| **188** | **EUCIV** | **2009** | **2009** | **FTA** | **0** | **1** | **0** |
| **189** | **EUCMR** | **2009** | **2009** | **FTA** | **0** | **1** | **0** |
| **190** | **JPNCHE** | **2009** | **2009** | **FTA** | **0** | **1** | **0** |
| **191** | **JPNVNM** | **2009** | **2009** | **FTA** | **0** | **1** | **0** |
| **192** | **MERCIND** | **2009** | **2009** | **PSA** | **0** | **0** | **1** |
| 193 | PANHND | 2009 | 2009 | FTA | 0 | 1 | 0 |
| 194 | PERSGP | 2009 | 2009 | FTA | 0 | 1 | 0 |
| **195** | **USAOMN** | **2009** | **2009** | **FTA** | **0** | **1** | **0** |
| **196** | **USAPER** | **2009** | **2009** | **FTA** | **0** | **1** | **0** |
| 197 | INDNPL | 2010 | 2009 | PSA | 0 | 0 | 1 |
| 198 | EUPNGFJI | 2011 | 2009 | FTA | 0 | 1 | 0 |
| **199** | **ASEANCER** | **2010** | **2010** | **FTA** | **0** | **1** | **0** |
| **200** | **ASEANIND** | **2010** | **2010** | **FTA** | **0** | **1** | **0** |
| **201** | **ASEANKOR** | **2010** | **2010** | **FTA** | **0** | **1** | **0** |
| 202 | EFTAALB | 2010 | 2010 | FTA | 0 | 1 | 0 |

**WTO's Database of RTAs**

| Count | RTA NAME | YEAR NOTIFIED | YEAR ENTERED INTO FORCE | RTA TYPE | CU | FTA | PSA |
|---|---|---|---|---|---|---|---|
| 203 | EFTASRB | 2010 | 2010 | FTA | 0 | 1 | 0 |
| **204** | **EUMNE** | **2010** | **2010** | **FTA** | **0** | **1** | **0** |
| 205 | EUSRB | 2010 | 2010 | FTA | 0 | 1 | 0 |
| **206** | **INDKOR** | **2010** | **2010** | **FTA** | **0** | **1** | **0** |
| 207 | PERCHN | 2010 | 2010 | FTA | 0 | 1 | 0 |
| **208** | **TURMNE** | **2010** | **2010** | **FTA** | **0** | **1** | **0** |
| 209 | TURSRB | 2010 | 2010 | FTA | 0 | 1 | 0 |