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CGE MODELIGNG OF THE 2018 STEEL AND ALUMINUM TARIFFS

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ABSTRACT

This paper seeks to estimate the effects of the 2018 steel and aluminum tariffs on the U.S. and on the foreign trade market. To do this, a Computable General Equilibrium (CGE) model is implemented to conduct counterfactual analysis on the tariff changes. The model used in this paper comes from Caliendo and Parro (2015) and is a multi-sector, multi-country model, with intermediate goods. The results from computing the general equilibriums from the tariff changes show that the U.S. increases its welfare by 0.0260%, the U.S. decreases its real wages by 0.0811%, and that, overall, the volume of trade for other countries and the terms of trade for other countries decreases worldwide. These results support the idea that the U.S. is shifting the weight of these tariffs onto other countries by causing a significant decrease in demand of imported goods.

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Chapter 1

Introduction

From 2017 to 2019, President Donald Trump announced a series of tariffs on multiple products to encourage domestic production, to decrease the U.S. trade deficit, and to retaliate against China for theft of intellectual property. These U.S. tariffs were quickly met by similar retaliatory tariffs from Canada, the EU, Mexico, and China. So now, many people wonder about the possibility of global trade war and also wonder about the implications these tariffs might have on producers and consumers in the U.S.

I want to learn how these tariffs will impact U.S. markets, global welfare, and global trade. To accomplish this, I will be conducting counterfactual analysis specifically on the 2018 Trump steel and aluminum tariffs in a multi-sector multi-country model of trade.

This thesis will be organized in the following way. First, I will give an overview of the Trump Tariffs, give a general overview of U.S. trade, explain the basic economic impacts of a tariff, and explain the Bush 2002 steel tariffs as a point of reference for the 2018 tariffs. Then I will explain how I set up my model by explaining the basics of the model used in Caliendo's and Parro's 2015 work "Estimates of the Trade and Welfare Effects of NAFTA" and then I will explain how it is used in counterfactual analysis. Once I have explained the model, I shall show my results and then conclude with a discussion on the data. By completing this thesis, I intend to add to the pool of research that has been done on forecasting trade policy impacts and add my own insight on how these tariffs might impact the world.

Chapter 2

Background

History of Trump Tariffs

In 2018, under Donald Trump's presidency, the U.S. would put in place a large list of tariffs that would continue to grow as the year went on. The first set of tariffs that were put in place were tariffs on washing machines and solar panels. On January 22, 2018, tariffs were placed on $8.5 billion worth of imports on solar panels and $1.8 billion of washing machines due to findings from the U.S. International Trade Commission that stated these industries were being harmed by imports (Brown and Kolb, 2018). Later, on March 1, 2018, Trump had stated that the U.S. would be imposing a 25% tariff on all U.S. steel imports and a 10% tariff on all aluminum imports which would become effective March 23, 2018 (Brown and Kolb, 2018). The White House Fact Sheets stated that this was specifically put into place "to protect America's critical steel and aluminum industries, which have been harmed by unfair trade practices and global excess capacity." These tariffs would be applied worldwide except for some exemptions, specifically Australia, South Korea, Argentina, Brazil, Mexico, Canada, and the European Union. However, later on June 1, 2018, these exemptions for Mexico, Canada, and the European Union, would be revoked (Brown and Kolb, 2018).

These tariffs would be the first of many that would follow in the upcoming months. After the announcement of the steel and aluminum tariffs, the U.S. released a report of findings of unfair trade practices with China and announced another set of tariffs planned against China on approximately $60 billion of Chinese goods for retaliation (Brown and Kolb, 2018). Shortly after these tariffs were put in place, on April 3, another 25% tariff on $50 billion of Chinese goods was announced (Brown and Kolb, 2018). Later on July 6, 2018 $34 billion worth of the previously proposed tariffs go into effect (Brown and Kolb, 2018). Finally, on September 17 the U.S. announced a 10% tariff on $200 billion worth of Chinese goods which would start on September 24 and increase to 25% by the end of the year (Brown and Kolb, 2018).

The implementation of these U.S. tariffs hadn't gone unchecked of course. Several countries applied retaliatory tariffs in response to the tariffs placed on steel and aluminum as well as the tariffs placed on China. Countries that did this include China, the EU, Canada, Japan, India, Russia, and Mexico. These retaliatory tariffs did impact the U.S. and because of pressure the U.S. was feeling from countries like China in its agricultural market, a subsidy for American farmers was also put in place on July 24, for products that were being targeted by retaliatory tariffs such as soybeans, corn, nuts, fruit, and beef (Brown and Kolb, 2018).

U.S Trade Relations

To understand the certain impacts these tariffs can have, one can look towards the importance of the U.S. in the foreign trade market. According from data from the World Integrated Trade Solution website (WITS), over the past 10 years the U.S. has consistently been the number one spender in the world on imports. To put this into context for recent years, the United States Census Bureau website had reported in 2017 that the U.S. had imported $2,342.9 billion worth of goods from the rest of the world. Some of the U.S.'s main trading partners can be seen from the top 5 countries that the U.S. had imported from that year: China, Canada, Mexico, Japan, and Germany. China specifically had been the top import source with $505.6 million worth of imports demanded that year. The U.S. trade balance dated on December 2017, from the Federal Reserve Economic Database (FRED), was stated to be -$51,889 million and the U.S. balance of trade has been known to be negative stretching back to as far as 1992.

Because the U.S. is known to be one of the top importers of the world, it was concerning to many when Trump announced these series of tariffs. Because the U.S. acts as one of the biggest importers in the world, many countries have a large reason to worry about the impact the tariffs may cause on the market for imports.

Basics of an Import Tariff

To understand some of the basic economic principles underlying this U.S. trade policy, it is essential to understand what is a tariff. An import tariff is a tax on imports. Specifically, import tariffs are often used to support domestic industries that sell goods at a higher price than cheaper foreign competition. Under the assumption of perfect competition and classical economic theory, letting a country freely trade with the rest of the world causes a demand for imported goods if the world price of that good is below the country's domestic equilibrium price of that good. When a country introduces an import tariff, the domestic price of a good effectively rises in the country of the tariff, causing a decrease in the amount of goods imported. With the implementation of an import tariff, consumer surplus decreases, producer surplus increases, government revenue increases, and dead weight loss is introduced as a loss of overall welfare.

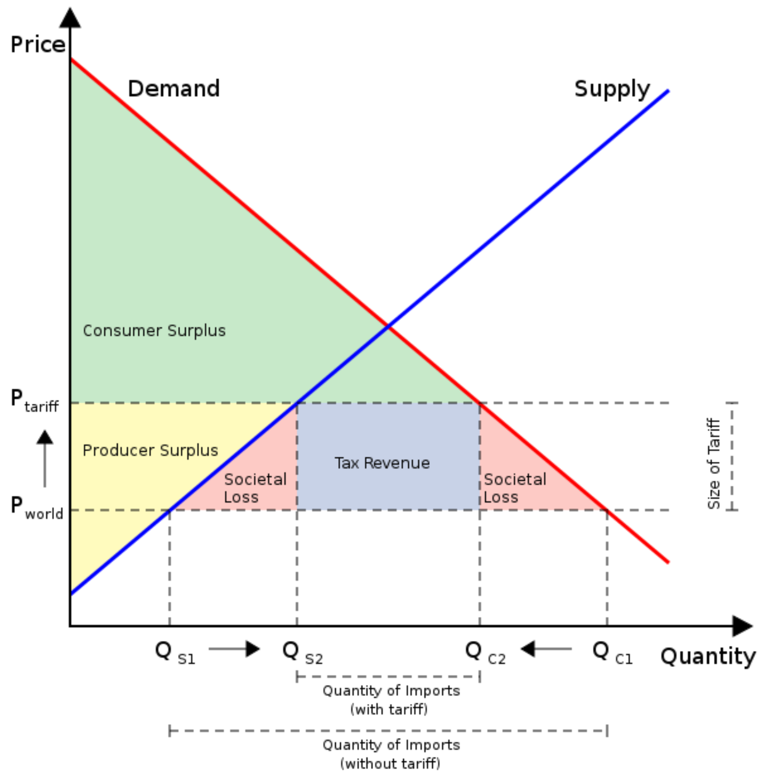

Figure 1. A supply and demand graph showing the effect of a tariff on imports, by Mgunn, December 12 2006, retrieved from https://en.wikipedia.org/wiki/File:EffectOfTariff.png

Because of this deadweight loss, it is argued that tariffs end up harming the countries that implement them rather than supporting them. The exception to this however can be considered with countries with larger market influence. Because some countries control a substantial amount of demand for imported goods, they can influence the world price of a good when they implement a tariff. Specifically, when a larger country introduces a tariff, it causes the demand for imports to fall which lowers the world price so that when the tariff is implemented, it is added onto the lower world price instead of the original world price. Because of this, there is additional government revenue earned in the home country while the welfare of the other foreign countries decreases because of the shift in weight of the tariff. Because of this it is possible to impose a tariff in a large country that increases national welfare if the increased government revenue exceeds the deadweight loss of a tariff.

However, the reason why many countries opt to not impose these kinds of welfare optimizing tariffs is because of the fear of retaliatory tariffs from other countries which would offset the increase in national welfare. In the case of the 2018 Trump tariffs, it could be argued that the implementation of these tariffs caused more harm than good however because of the retaliatory tariffs from the other countries.

2002 Bush Steel Tariffs

To put into perspective the current 2018 steel and aluminum tariffs, one can look back to the 2002 Bush steel tariffs. In 2002, the domestic manufacturers of steel in the U.S. were having major financial problems. About 30% of the domestic steel industry was bankrupt at the time and the prices on US steel were at a 20-year low (Read, 2005). Because of this, many steel manufactures in the U.S. were asking for higher tariffs on steel.

President Bush had come in to office with promises to bring back steel production to the U.S. So, to help bring back demand for domestic steel, on March 5, 2002, he placed three-year safeguard tariffs on 11 different steel products with the highest rates reaching 30% (Cooney, 2003). These tariff rates were significantly higher than what was recommended by the U.S. trade commission, but Bush gave his reasoning as to “give breathing space to restructure and become newly competitive” for the domestic steel industry (Read, 2005). These tariffs were to remain in place for over 3 years and then eventually reduce once the domestic steel market regained some power. However, these tariffs would eventually end earlier than expected because of foreign pressures.

The first roadblock to these tariffs came from the World Trade Organization (WTO) in 2003. The reasoning behind the legality of the Bush 2002 tariffs on steel came from the statement that the U.S. had been seeing a surge of steel imports from other countries in the past few years which should allow for the U.S. to be able to put up tariffs to protect its steel industry. However, the WTO's findings did not find a surge in steel imports for the U.S. during the 2002 time period and therefore the tariffs were in violation of their tariff commitments with the U.S. Because of this the European Union threatened to place $2 billion worth of sanction on the U.S. products such as oranges and certain automobiles. This prompted the U.S. to quickly retract its tariffs on December 4, 2003.

Even though these tariffs were only in place for a year, the expected effects and impact on the U.S. economy were leaning toward negative. U.S. automobile, heavy equipment, construction and other steel-consuming industries were suspected to be affected because of the increased cost of steel. Francois and Baughman (2001) estimated that consumers would spend up to $1.9 to $4 billion extra year, U.S. national income would end up being reduced by $1.4 billion a year, and U.S steel producers would gain up to $242 to $496 million a year. This idea of higher domestic steel prices was also reaffirmed by a predicted increase of 3.3% in a 2003 paper by Hufbauer and Goodrich.

However, it is questionable as to whether or not these estimations over exaggerated the negative effects in U.S. welfare. Lee (2004) used a dynamic multi country CGE model to evaluate the effects of the 2002 steel tariffs. His results showed relatively small negative changes with U.S GDP decreasing an estimated $117-118 million instead of Francois and Baughman's reported $1.4 billion. What he did find was that most of the countries that were facing this tariff such as China, Japan, the EU, and Canada, were taking most of the losses in welfare for the U.S. In his paper he states that results from the study done by Francois and Baughman could be misleading as they used tariff rates that were much higher than estimated in his study and because they excluded important trading partners in their model which were Canada and Mexico.

To summarize, the 2002 steel tariffs was estimated to have a positive effect on domestic U.S steel manufactures and U.S. welfare was shown to slightly decrease because of the increased cost of steel which affected other U.S. manufactures. Foreign welfare was seen to take a hit from these tariffs and is a reason for why retaliatory tariffs were threatened to be enacted.

Chapter 3

Methodology

Model

To solve for the general equilibrium of the U.S. and other countries that the Trump tariffs affected, I used the modeling techniques implemented in Caliendo and Parro (2015). In their paper, they create a multi-country, mutli-sector model which incorporates tradable and non-tradable intermediate goods. This model takes elements from the Eaton Kortum (2002) model of trade and expands upon it to allow for trade across multiple sectors. In this model, markets are assumed to be perfectly competitive, labor can be moved across sectors without incurring any costs, and trade across countries does not have to be balanced, however trade across the world is balanced.

By using a model that accounts for multiple sectors, the effect of the tariffs on steel and aluminum will be able to be seen across other sectors since they are used as intermediate goods. In this model, countries are denoted by subscript n and sectors are denoted by superscript j.

Consumption

In a world which consists of N countries and J sectors per country, country n has L_n representative households which demand final goods according to a Cobb Douglas utility function. These households demand final goods C_n^j according to the utility function

$$U(C_n) = \prod_{j=1}^{J} {C_n^j}^{\alpha_n^j} \ \ where \ \ \sum_{j=1}^{J} \alpha_n^j = 1$$

Each of these households receives an income I_n, which comes from two sources: labor and transfers. The income derived from labor is equal to $L_n * w_n$, where L_n is the supply of labor and w_n is the labor rental rate (wages). The income derived from transfers comes in the form of a lump sum of revenue that is gained by the tariffs combined with the current trade deficit in the country.

Intermediate Goods

In country *n*, in sector *j*, there is assumed to be an infinite number of tradable goods. Therefore, we denote a continuum of tradable intermediate goods by ω^j. These intermediate goods are produced from two factors of production: labor and composite intermediate goods obtained from other sectors. Composite intermediate goods are goods that are used in the production of other intermediate goods and are goods that are included in consumption C_n^j as final goods. The production of these intermediate goods follows from the equation

$$q_n^j(\omega^j) = z_n^j(\omega^j) * l_n^j(\omega^j)^{\gamma_n^j} * \prod_{k=1}^{J} m_n^{k,j}(\omega^j)^{\gamma_n^{k,j}}$$

$z_n^j(\omega^j)$ represents the efficiency in producing ω^j, $l_n^j(\omega^j)$ represents labor used in production of ω^j, and $m_n^{k,j}(\omega^j)$ represents composite intermediate goods from sector *k* used in production of ω^j. Also, γ_n^j and $\gamma_n^{k,j}$ represent the share of value added and the share of materials from sector *k* used in production of ω^j.

Because markets are perfectly competitive and the production of ω^j is constant returns to scale, producers will price an intermediate good according to its unit cost. This implies the cost of an input bundle c_n^j is

$$c_n^j = B_n^j * w_n{}^{\gamma_n^j} * \prod_{k=1}^{J} P_n^k{}^{\gamma_n^{k,j}}$$

where B_n^j is a constant and P_n^k is the price of a composite intermediate good in sector *k*.

With r_n^j representing the demand of intermediate goods and σ^j, representing the elasticity of substitution of intermediate goods, suppliers of composite intermediate goods follow the production function

$$Q_n^j = [\int r_n^j(\omega^j)^{\left(1-\frac{1}{\sigma^j}\right)} d(\omega^j)]^{\frac{\sigma^j}{\sigma^j-1}}$$

From this production function, demand r_n^j and prices P_n^k can be derived for the composite intermediate goods.

Trade

Trade in this model has two costs associated with it: tariffs and iceberg costs. Iceberg costs, d_{ni}^j, model the cost of exporting goods from sector *j* of country *n* to country *i*. Tariffs τ_{ni}^j on country *i* from country n are ad-valorem tariffs. From the Eaton Kortum 2002 model, we assume that $z_n^j(\omega^j)$, the efficiency of producing ω^j, is drawn from a Fréchet distribution

$$F_n^j(z_n^j) = e^{[-\lambda_n^j * z_n^j{}^{(-\theta^j)}]}$$

In this distribution, λ_n^j determines the location of the distribution and θ^j, the sectoral dispersion of productivity, determines the shape of the distribution. Knowing this, the price index for the optimal bundle of j-type varieties in country n can be derived to be:

$$P_n^j = A^j * [\sum_{i=1}^{N} \lambda_i^j * \left(c_i^j * \left(1 + \tau_{ni}^j\right) * d_{ni}^j\right)^{(-\theta^j)}]^{\left(\frac{-1}{\theta^j}\right)}$$

The derivation of this equation from Caliendo and Parro (2015) can be found in appendix A because of its length. In this equation A^j serves as a constant.

And expenditure shares, the fraction of goods country n bought from country *i*, can be written as

$$\pi_{ni}^j = \frac{\lambda_i^j * \left(c_i^j * \left(1 + \tau_{ni}^j\right) * d_{ni}^j\right)^{(-\theta^j)}}{\sum_{h=1}^{N} \lambda_h^j * \left(c_h^j * \left(1 + \tau_{nh}^j\right) * d_{nh}^j\right)^{(-\theta^j)}}$$

Total Expenditure and Trade Balance

Total expenditure X_n^j is a measure of money spent on composite intermediate goods and money spent on the consumption of final goods. In this model X_n^j can be described as

$$X_n^j = \sum_{k=1}^{J} \gamma_n^{j,k} * \sum_{i=1}^{N} X_i^k * \frac{\pi_{in}^k}{1 + \tau_{in}^k} + \alpha_n^j * I_n$$

$$where\ I_n = w_n * L_n + R_n + D_n$$

Here I_n represents final absorption where $w_n * L_n$ represents labor income. Because we make trade balanced across the world but not across countries in this model, we allow for countries to have trade surpluses/deficits called D_n and the revenue collected from tariffs in country *n* is called R_n. (R_n specifically equals $\sum_{j=1}^{J}\sum_{i=1}^{N} X_n^j * \frac{\pi_{ni}^j * \tau_{ni}^j}{1+\tau_{ni}^j}$)

The last equation that is important for trade in this model is:

$$\sum_{j=1}^{J}\sum_{i=1}^{N} X_n^j * \frac{\pi_{ni}^j}{1+\tau_{ni}^j} - D_n = \sum_{j=1}^{J}\sum_{i=1}^{N} X_i^j * \frac{\pi_{in}^j}{1+\tau_{in}^j}$$

This equation shows in principle that a country's total spending on imports minus its trade deficits should be equal to total revenue from its exports. Therefore, this acts as the market clearing condition in trade for a country.

Measuring the changes in Equlibria

To measure the characteristics of the general equilibrium under a tariff structure τ', we solve for the changes in wages and prices by modeling a change in the tariff structure, τ to τ'. By doing this, the model can be calibrated to the data of a base year and it allows for two variables in the model, γ_n^j and d_{ni}^j, to not need to have to be estimated. In this model, Caliendo and Parro also make use of what is called hat algebra. A variable $\hat{x}$ (x hat) is defined as $\hat{x} = \frac{x'}{x}$. This is done to represent the relative change in the variable *x* over the time period in which τ changes to τ'.

Given wage vectors *w* and w' and price vectors P and τ', a general equilibrium of τ' relative to τ can be defined as the vectors ($\hat{w}$, $\hat{P}$) that satisfy the following equlibria conditions:

$$(\widehat{1+\tau'}{}_{ni}^{j}) = \frac{(1+\tau'^{j}_{ni})}{(1+\tau_{ni}^j)}$$

$$\widehat{c_n^j} = \widehat{w_n}^{\gamma_n^j} * \prod_{k=1}^{J} \widehat{P_n^k}^{\gamma_n^{k,j}}$$

$$\widehat{P_n^j} = [\sum_{i=1}^{N} \pi_{ni}^{j} * \left(\widehat{c_i^j} * \left(\widehat{1+\tau_{ni}^j}\right)\right)^{(-\theta^j)}]^{\left(\frac{-1}{\theta^j}\right)}$$

$$\widehat{\pi_{ni}^j} = \left(\widehat{c_i^j} * \frac{\left(\widehat{1+\tau_{ni}^j}\right)}{\widehat{P_n^j}}\right)^{\left(-\frac{1}{\theta^j}\right)}$$

$$X'^{j}_{n} = \sum_{k=1}^{J} \gamma_n^{j,k} * \sum_{i=1}^{N} X'^{k}_{i} * \frac{\pi'^{k}_{in}}{1+\tau'^{k}_{in}} + \alpha_n^j * I'_n$$

$$\sum_{j=1}^{J} \sum_{i=1}^{N} X'^{j}_{n} * \frac{\pi'^{j}_{ni}}{1+\tau'^{j}_{ni}} - D_n = \sum_{j=1}^{J} \sum_{i=1}^{N} X'^{j}_{i} * \frac{\pi'^{j}_{in}}{1+\tau'^{j}_{in}}$$

$$I'_n = w'_n * w_n * L_n + R'_n + D'_n$$

Data Collection

Model Specifics

I decided to model 18 tradable sectors and 15 non-tradable sectors using International Standard Industrial Classification (ISIC) Revision 3 codes and I decided to model the 30 countries used in Caliendo and Parro (2015). I also included a composed Rest of World (ROW) in my model as the 31st country. This specific list of countries and sectors can be found in appendix B.

Calculating Variables from the Data

To calculate the general equilibrium from above, data on several variables will needed. Specifically, these are bilateral expenditure, value added, and gross production. Additionally, input output tables, I-O, tables are also needed. With the data on these variables and the I-O tables, we can calculate several variables within the model which are $\gamma_n^{k,j}$, γ_n^j , π_n^j, and α_n^j

γ_n^j, the share of value added, can be found by dividing the value added per sector by the gross income of each sector, $\frac{V_n^j}{Y_n^j}$. The share of *k*'s spending on goods from *j*, $\gamma_n^{k,j}$, can be found from dividing the share of consumption of goods from sector *j* in sector *k* by the total consumption of sector *k*. π_n^j, the bilateral trade share is the bilateral expenditure on goods from country *i* divided by the total import expenditure of country *n*. Finally, α_n^j is given by the equation:

$$\alpha_n^j = \frac{Y_n^j + D_n^j - \sum_{k=1}^{J} \gamma_n^{k,j} * Y_n^j}{I_n}$$

The only other variable needed to solve for the general equilibrium under τ' is θ^j, the trade elasticities across sectors. In Caliendo and Parro (2015) they estimate θ^j over 20 different tradable sectors using ISIC Rev. 3 codes to index the sectors. For the purpose of this paper, the trade elasticities of the 18 tradable sectors in my model will be taken from the table below:

Table 1: Dispersion of Productivity Values for Tradable Sectors

Sector	θ^j
Agriculture	9.11
Mining and quarrying	13.53
Food	2.62
Textiles	8.1
Wood	11.5
Paper	16.52
Petroleum	64.85
Chemicals	3.13
Plastics	1.67
Minerals	2.41
Basic Metals	3.28
Metal Products	6.99
Machinery	1.45
Office	12.95
Electrical	12.91
Auto	8.22
Other Transport	8.22
Other	3.98

As for the non-tradable sectors, a value of 8.22 was used as this was the mean value of the manufacturing tradable sectors in Caliendo and Parro (2015).

Data Sources

Since the earliest data in my data set was bilateral trade flows from 2011, I decided to use 2011 as my base year. I used data on bilateral trade flows from the OECD.Stat website from their STAN Archives. As for value added, gross production, and the input output tables, I used the raw 2011 data set from the OECD Inter-Country Input-Output (ICIO) Tables from the OECD website. The only other data collected, was the tariff rates in 2011 and the tariff rates after the 2018 steel and aluminum tariffs were applied. Using the same method used in Guo, Lu, Sheng, and Yu (2017), I set the tariff rates that one country applies to any other country or sector to be all the same since all of the countries I used in this model are members of the World Trade Organization (WTO) and therefore have to abide by Most Favorable Nation rule. This rule states that any member of the WTO must apply the same trade procedures when dealing with any other nation in the WTO. Using data from the World Bank website, I used their weighted mean MFN tariff rates as my tariff rates. As for quantifying the 2018 tariff changes, I represented this increase by increasing the tariff rates that the U.S. applies on its Basic Metals sector to every other country in the model, except the four exceptions of Argentina, Australia, Brazil, and Korea.

Chapter 4

Results

From calculating the GE of my model I found these to be the changes in welfare, volume of trade (VoT), and terms of trade (ToT) across countries:

Table 2: Changes in Welfare, Volume of Trade (VoT), and Terms of Trade (ToT) in %

Country	Welfare	VoT	ToT	Country	Welfare	VoT	ToT
Argentina	-0.0109	-0.0029	-0.0080	Italy	-0.0015	-0.0004	-0.0011
Australia	-0.0089	-0.0004	-0.0085	Japan	0.0020	-0.0002	0.0021
Austria	-0.0109	-0.0012	-0.0097	Korea	-0.0022	0.0000	-0.0022
Brazil	-0.0010	0.0008	-0.0017	Mexico	-0.0815	-0.0106	-0.0709
Canada	-0.0910	-0.0124	-0.0786	Netherlands	-0.0096	-0.0006	-0.0090
Chile	-0.1005	-0.0122	-0.0883	New Zealand	-0.0070	-0.0006	-0.0064
China	-0.0011	0.0000	-0.0011	Norway	-0.0231	-0.0026	-0.0205
Denmark	-0.0062	-0.0002	-0.0060	Portugal	-0.0161	-0.0007	-0.0154
Finland	-0.0071	-0.0010	-0.0061	South Africa	-0.0517	-0.0136	-0.0381
France	-0.0036	-0.0004	-0.0032	Spain	-0.0052	-0.0003	-0.0048
Germany	-0.0032	-0.0007	-0.0025	Sweden	-0.0129	-0.0013	-0.0116
Greece	-0.0071	-0.0005	-0.0067	Turkey	-0.0121	-0.0027	-0.0094
Hungary	-0.0238	-0.0012	-0.0226	UK	-0.0089	-0.0010	-0.0079
India	-0.0132	-0.0050	-0.0082	US	0.0260	-0.0046	0.0306
Indonesia	0.0002	-0.0006	0.0008	ROW	-0.0034	-0.0010	-0.0024

Ireland	-0.0158	-0.0007	-0.0151				

The first point to notice looking at these results is that U.S. welfare increased by 0.0260%. This is due to their 0.0306% increase in their ToT overshadowing their 0.0046% decrease in VoT. For the majority of other countries used in this model, overall welfare decreased. However, there were two countries other than the U.S. that increased their welfare and these two countries were Indonesia and Japan. Both of these countries managed to receive an increase in welfare because their increase in ToT overshadowed their losses in VoT. Overall, 28 out of the 31 countries, including ROW, experienced a decrease in VoT and 28 out of the 31 countries also experienced a decrease in ToT. The three countries with the highest increase in welfare were the U.S., Japan, and Indonesia respectively. The three countries with the highest decrease in welfare were Chile, Canada, and Mexico respectively.

Looking at U.S. specifically, the changes in VoT and the changes in ToT can be broken down sectorally:

Table 3: Sectoral Influence on Changes in VoT and ToT for U.S. in %

Sector	Contribution to Changes in ToT	Contribution to Changes in VoT	Sector	Contribution to Changes in ToT	Contribution to Changes in VoT
Agriculture	0.32	-0.42	Minerals	0.30	-0.23
Mining and Quarrying	3.59	-17.79	Basic Metals	20.58	188.34
Food	1.51	-0.83	Metal Products	9.13	-10.41

Textiles	-0.22	-0.18	Machinery	18.38	-1.36
Wood	0.28	-0.38	Office	0.59	-3.44
Paper	0.40	-0.60	Electrical	14.26	-20.28
Petroleum	2.21	-1.75	Auto	15.58	-23.09
Chemicals	1.11	0.01	Other Transport	10.13	-3.63
Plastics	0.78	0.39	Other	1.07	-4.34

This table shows the contribution each sector had in changing the ToT and VoT for the U.S. When looking at the 0.0306% increase in the U.S.'s ToT, the Basic Metals sector accounts for 20.58% for this positive change. This was the sector where the steel and aluminum tariffs were put directly in place. Other sectors that significantly contributed to the U.S.'s increase in ToT were Metal Products, Other Transport, Electrical, Auto, and Machinery.

When looking at the 0.0046% decrease in the U.S.'s ToT, the Basic Metals sector accounts for 188.34% for this negative change. This was the only sector that accounts for more than 1% of the negative change in the VoT. Other sectors that instead had a significant positive effect on the U.S.'s VoT were Mining and Quarrying, Metal Products, Electrical, and Auto.

To see the impact of the U.S.'s tariffs on its foreign trade, the table below displays the change in the U.S.'s imports in response to the change in tariffs, any additional results on other countries can be found in Appendix C:

Table 4: Change in U.S. Imports from Country in %

Country	US's Change in Imports from Country	Country	US's Change in Imports from Country
Argentina	4.88	Ireland	-0.01
Australia	4.82	Italy	-1.72
Austria	-4.44	Japan	0.15
Brazil	3.89	Korea	3.63
Canada	-3.00	Mexico	-2.02
Chile	-23.83	Netherlands	-2.35
China	0.36	New Zealand	-3.20
Denmark	0.04	Norway	-9.57
Finland	-6.46	Portugal	0.21
France	-0.92	South Africa	-22.44
Germany	-1.56	Spain	-2.84
Greece	-13.14	Sweden	-6.66
Hungary	0.71	Turkey	-6.20
India	-1.86	UK	-1.78
Indonesia	-0.46	ROW	-2.08

This table shows that the U.S. decreases its imports from a majority of countries in response to the implementation of its own tariffs. Out of its 30 trading partners in this model, the U.S. had decreased its imports with 21 of them. The countries that had received the largest percentage increase in import demand were Argentina, Australia, Brazil and Korea. This makes sense as these four countries were the countries that were exempt from these tariffs.

Finally, the last table below shows the effect of the 2018 steel and aluminum tariffs on real wages:

Table 5: % Change in Real Wages

Country	Change in Real Wages	Change in Real Wages	Change in Real Wages
Argentina	-0.0088	Japan	0.0023
Australia	-0.0084	Korea	-0.0022
Austria	-0.0099	Mexico	-0.0743
Brazil	-0.0017	Netherlands	-0.0091
Canada	-0.0800	New Zealand	-0.0064
Chile	-0.0939	Norway	-0.0216
China	-0.0010	Portugal	-0.0158
Denmark	-0.0062	South Africa	-0.0403
Finland	-0.0061	Spain	-0.0050
France	-0.0031	Sweden	-0.0119
Germany	-0.0024	Turkey	-0.0098
Greece	-0.0069	UK	-0.0079
Hungary	-0.0233	US	-0.0811
India	-0.0090	ROW	-0.0025
Indonesia	0.0009	Japan	0.0023

Ireland	-0.0155	Korea	-0.0022
Italy	-0.0011	Mexico	-0.0743

This table shows that, overall, the implementation of these tariffs causes real wages to decline worldwide. The only two countries that do not follow this trend are Indonesia and Japan. These were the only two countries that had a positive change in welfare other than the U.S.

The U.S., unlike the two previous countries, had a decrease in real wages that was the second largest decrease in real wages in this model. Its real wages had decreased 0.0811% because of the implementation of the tariffs.

Chapter 5

Conclusion

The results of this CGE model on the 2018 steel and aluminum Trump Tariffs, have shown that these tariffs do have a small and positive impact on U.S. welfare and have, overall, a negative effect on global welfare. The estimated increase in welfare for the U.S. was 0.0260%, which could be attributed to a 0.0306% increase in its ToT while only having a 0.0046% decrease in its VoT. These findings suggest that the U.S. does have enough power in the export market to cause an increase in its welfare from applying these tariffs. This increase might be due to an increase in export prices of the Basic Metals, Metal Products, Other Transport, Electrical, Auto, and Machinery sectors since these sectors contributed the most in the increase in ToT for the U.S.

As for imports, the U.S. was seen to have an overall decrease in the percentage of imports from the world. On average, the U.S. was estimated in having an average reduction of imports of 3.26%. Because of this reduction in imports, U.S. domestic steel and aluminum producers are likely to see an increase in welfare as this lowers competition from foreign competitors.

The last notable piece of data from these results was the U.S.'s decrease in real wages. The U.S. was found to have the second largest reduction in real wages because of these tariffs. Real wages in the U.S. was estimated to decrease 0.0811%.

When overviewing my work, I can concede that there are some limitations and shortcomings to my results and data. The first limitation I had was the size of my data. In an ideal setting, I would be able to collect data on every country to create the best possible GE model. With less data, my results are less precise and do not capture the true GE of the World. Another limitation in my model was using the mean MFN tariff rates for a country as equal across all its sectors. I had used this rule in my model because it was hard to find MFN tariff rates for a country sector by sector. Therefore, since I used the mean MFN tariff rates instead of the specific tariff rates by sector, my model was less precise. The last possible limitation I had within my model was the precision of the tariff rates I used on the basic metals sector. Because steel and aluminum are only a portion of what makes up the basic metals sector, I had to estimate the effect of the steel and aluminum tariffs on the basic metals sector instead of knowing the actual value.

Currently, as of March 2019, these Trump tariffs are beginning to slow and are possibly being revoked. After the long battle of tariffs between China and the U.S., on December 1, 2018, the possibility of a U.S.-China Tariff Truce appeared when Presidents Trump and Xi announced they would stop applying additional tariffs at the moment to hopefully negotiate a trade deal in the near future (Brown and Kolb, 2018). This also may hold true with the steel and aluminum tariffs as the Department of Commerce has given President Trump 90 days to agree or disagree with their report submitted that indicated the steel and aluminum tariffs were expected to damage the auto producers and auto part producers in the U.S. (Brown and Kolb, 2018).

These decisions might be being made because of the amount of retaliatory tariffs placed against the U.S. In this paper, retaliatory tariffs were not taken into account but if they were, it is likely that U.S. welfare would decrease. However, assuming no retaliatory tariffs were put into place, these 2018 steel and aluminum tariffs can be seen as a way of increasing U.S. welfare overall.

Appendix A

Derivation of Price Index for the Optimal Bundle of j-type varieties in Country n

The efficiency of country n in producing an intermediate good ω^j in sector j is the realization of a random variable z_i^j drawn for each ω^j in each sector j from the distribution

$$F_n^j(z) = e^{-\lambda_n^j * z^{(-\theta^j)}}$$

Therefore, the cost of purchasing an intermediate good ω^j from country i, is the realization of the random variable

$$p_{ni}^j(z_i^j) = \frac{[c_i^j * (1 + \tau_{ni}^j) * d_{ni}^j]}{z_i^j}$$

First note that $p_{ni}^j(z_i^j)$, has a Fréchet distribution, in particular

$$\Pr[p_{ni}^j \leq p] = 1 - e^{-T_{ni}^j * p^{\theta^j}}$$

$$where\ T_{ni}^j = [\lambda_n^j * c_i^j * (1 + \tau_{ni}^j) * d_{ni}^j]^{-\theta^j}$$

Given this, the lowest price of an intermediate good ω^j in country n, $p_n^j(\omega^j)$, also has a Fréchet distribution,

$$\Pr[p_n^j \leq p] = 1 - \prod_{i=1}^{N} \Pr[p_{ni}^j \geq p]$$

and by using both of these equations we obtain

$$\Pr[p_n^j \leq p] = 1 - e^{-\phi_n^j * p^{\theta^j}}$$

$$where\ \phi_n^j = \sum_{i=1}^{N} T_{ni}^j$$

Note that since $p_n^j(\omega^j)$ is Fréchet with shape parameter θ^j, $p_n^j(\omega^j)^{\theta^j}$ is an exponential distribution. To see this, define the function $g(x) = x^{\theta j}$and suppose that x has a Fréchet distribution with location parameter ϕ^j and shape parameter θ^j. Let $f_x(x)$ denote the density function of x, namely $f_x(x) = \theta^j * \phi_n^j * x^{\theta^j - 1} * e^{-\phi_n^j * x^{\theta^j}}$.

It follows that the density function of $y = g(x)$ is given by

$$f_y(y) = f_x(g^{-1}(y)) * |\frac{\delta g^{-1}(y)}{\delta y}|$$

Then since $g^{-1}(y) = y^{\frac{1}{\theta^j}}$, and $\frac{\delta g^{-1}(y)}{\delta y} = \theta^j * y^{\frac{1}{\theta^j}-1}$, the density function of y is $f_y(y) = \phi_n^j * e^{-\phi_n^j * y}$ which is an exponential distribution with parameter ϕ_n^j.

Given this result, the price index is

$$(P_n^j)^{1-\eta_j} = \int \phi_n^j * y^{(1-\eta_j)} * e^{-\phi_n^j * y}\, dy\,,$$

which follows since we have just derived that $y = p_n^j(\omega^j)^{\theta^j}$ has probability density function, $\phi_n^j * e^{-\phi_n^j * y}$. Now consider the change of variables $u = -\phi_n^j * y$. Then

$$(P_n^j)^{1-\sigma^j} = (\phi_n^j)^{\frac{-(1-\sigma^j)}{\theta^j}} * \int u^{\frac{1-\sigma^j}{\theta^j}} * e^{-\phi_n^j * y}\, dy$$

Which simplifies to

$$P_n^j = A^j * \phi_n^{j\frac{-1}{\theta^j}}$$

where $A^j = \Gamma(\xi^j)^{\frac{1}{1-\sigma^j}}$, and ξ^j is a Gamma function evaluated at $\xi^j = 1 + \frac{-(1-\sigma^j)}{\theta^j}$.

Appendix B

Tables of Countries and Sectors

Table 6: Table of Tradable Sectors

Sector	ISIC REV. 3 Code	Sector	ISIC REV. 3 Code
Agriculture	1 - 5	Minerals	26
Mining and Quarrying	10 - 14	Basic Metals	27
Food	15-16	Metal Products	28
Textiles	17-19	Machinery	29
Wood	20	Office	30
Paper	21-22	Electrical	31
Petroleum	23	Auto	34
Chemicals	24	Other Transport	351-359
Plastics	25	Other	36 -37

Table 7: List of Non-Tradable Sectors

Sector	ISIC REV. 3 Code	Sector	ISIC REV. 3 Code	Sector	ISIC REV. 3 Code
Electricity	40 - 41	Post	64	R&D Research and Other Business	73 -74
Construction	45	Finance	65 - 67	Public admin. and defense	75

Retail	50 - 52	Real Estate	70	Education	80
Hotels	55	Renting machinery	71	Health	85
Transport	60 -63	Computer	72	Other services	90-93

Table 8: Table of Countries

Countries				
Argentina	China	Hungary	Korea	South Africa
Australia	Denmark	India	Mexico	Spain
Austria	Finland	Indonesia	Netherlands	Sweden
Brazil	France	Ireland	New Zealand	Turkey
Canada	Germany	Italy	Norway	UK
Chile	Greece	Japan	Portugal	US

Appendix C

Full Table Results for All Countries

Table 9: % Change in Imports Part A

	Argen.	Australia	Austria	Brazil	Canada	Chile	China	Denmark	Finland	France
Argen.	0.00	-0.13	0.40	-0.04	4.54	1.33	0.20	0.12	0.36	0.31
Australia	0.15	0.00	0.47	-0.01	0.91	1.26	0.19	0.19	0.43	0.31
Austria	0.00	-0.13	0.00	-0.16	0.40	1.66	-0.10	0.07	0.13	0.04
Brazil	0.22	0.28	0.37	0.00	1.06	1.54	0.25	0.17	0.50	0.36
Canada	-2.70	-1.03	0.34	-1.06	0.00	-1.14	-0.09	0.20	0.33	0.10
Chile	-0.55	-0.72	-0.15	-0.77	0.33	0.00	-0.32	0.06	-0.12	0.28
China	0.14	0.02	0.23	-0.18	1.25	1.39	0.00	0.13	0.28	0.19
Denmark	-0.04	0.15	0.12	-0.21	0.77	1.05	-0.07	0.00	0.22	0.02
Finland	-0.07	-0.39	0.08	-0.47	0.67	2.07	-0.07	0.02	0.00	-0.08
France	0.00	-0.22	0.16	-0.31	1.18	0.88	-0.02	0.09	0.20	0.00
Germany	-0.01	-0.22	0.18	-0.32	1.12	0.98	0.01	0.09	0.15	0.13
Greece	-0.09	-0.15	0.05	-0.38	1.00	0.60	-0.07	0.01	0.03	-0.02
Hungary	0.00	0.00	0.16	-0.14	0.17	2.58	0.05	0.08	0.13	-0.06
India	-0.04	-0.27	0.14	-0.49	0.91	2.42	-0.01	0.12	0.22	0.23
Indonesia	0.01	-0.17	0.13	-0.54	0.81	2.62	-0.14	0.08	0.15	0.03
Ireland	-0.03	0.04	0.20	0.24	0.83	1.02	0.04	0.06	0.27	0.17
Italy	-0.01	-0.20	0.08	-0.37	0.87	0.73	-0.08	0.06	0.10	0.00
Japan	-0.01	-0.34	0.26	-0.44	0.97	1.90	0.14	0.16	0.29	0.22
Korea	-0.01	-0.12	0.32	-0.21	1.32	1.67	0.24	0.15	0.40	0.23
Mexico	0.71	-1.21	1.27	1.24	1.32	0.97	1.29	0.27	0.77	1.13
Netherlands	-0.02	-0.13	0.19	-0.28	2.77	1.55	0.03	0.09	0.14	0.05

New Zealand	0.04	0.01	0.29	-0.14	0.95	1.71	0.03	0.13	0.22	0.22
Norway	-0.14	-0.18	0.24	-0.42	0.07	1.13	0.00	0.03	0.17	0.06
Portugal	-0.12	-0.17	0.20	-0.39	1.02	1.87	0.01	0.06	0.20	0.03
South Africa	-0.17	-0.42	-0.16	-0.50	1.68	0.51	-0.38	-0.04	-0.18	-0.36
Spain	-0.06	-0.30	0.15	-0.39	0.93	1.53	-0.05	0.06	0.18	0.03
Sweden	-0.10	-0.36	0.07	-0.31	0.86	1.58	-0.10	0.01	0.07	-0.02
Turkey	-0.11	-0.13	0.06	-0.37	1.13	0.58	-0.12	0.03	0.08	0.03
UK	-0.02	-0.10	0.25	-0.27	1.05	1.07	0.03	0.09	0.26	0.08
ROW	-0.25	-0.22	-0.05	-0.60	1.00	1.45	-0.40	-0.02	0.01	-0.37

Table 10: % Change in Imports Part B

	Germany	Greece	Hungary	India	Indonesia	Ireland	Italy	Japan	Korea	Mexico
Argentina	0.26	0.35	0.40	0.24	0.12	0.07	0.27	0.05	0.12	0.23
Australia	0.37	0.18	0.61	0.33	0.28	0.09	0.28	0.09	-0.10	0.54
Austria	-0.08	0.00	0.08	0.08	0.00	0.05	-0.02	-0.10	-0.04	0.11
Brazil	0.25	0.25	0.34	1.12	0.29	0.14	0.37	0.19	0.05	0.33
Canada	1.24	-0.90	0.50	-0.32	-0.70	-0.16	0.07	1.71	0.79	1.84
Chile	0.31	0.15	0.27	0.04	-0.64	-0.06	0.17	0.08	0.18	0.26
China	0.15	0.30	0.30	0.26	0.17	0.15	0.15	0.00	-0.12	0.82
Denmark	-0.04	0.07	0.08	0.15	-0.01	0.03	0.04	-0.78	-0.11	0.21
Finland	-0.03	-0.26	0.05	0.52	-0.08	-0.04	0.03	-0.10	-0.67	0.16
France	0.10	0.13	0.13	0.17	0.11	0.05	0.09	-0.08	-0.32	0.22
Germany	0.00	0.06	0.24	0.10	0.01	0.04	0.10	-0.03	0.07	0.23

Greece	-0.04	0.00	0.07	0.54	-0.05	0.00	0.04	-0.04	-0.39	0.28
Hungary	-0.02	0.07	0.00	0.06	-0.01	0.06	-0.15	-0.11	0.02	-0.02
India	0.15	0.01	0.33	0.00	-0.11	0.05	0.12	-0.18	-0.50	0.82
Indonesia	-0.08	0.18	0.30	0.03	0.00	0.08	-0.04	-0.27	-0.86	0.37
Ireland	0.28	0.08	0.13	0.09	0.05	0.00	0.15	0.04	0.52	0.38
Italy	-0.02	0.04	0.08	0.08	-0.06	0.04	0.00	-0.11	-0.22	0.19
Japan	0.24	0.19	0.30	0.30	-0.12	0.16	0.23	0.00	-0.09	0.45
Korea	0.22	0.61	0.30	0.91	-0.04	0.06	0.23	0.15	0.00	0.79
Mexico	1.82	2.25	1.77	1.08	0.84	-0.07	1.03	2.31	1.90	0.00
Netherlands	0.03	0.11	0.16	0.26	0.02	0.07	0.10	0.03	-0.34	0.49
New Zealand	0.26	0.11	0.70	0.18	-0.01	0.05	0.23	-0.09	-0.45	0.43
Norway	0.03	0.07	0.13	0.14	0.02	-0.05	0.06	-0.08	0.54	0.26
Portugal	0.02	0.09	0.12	0.33	0.12	0.03	0.06	-0.09	-0.77	0.58
South Africa	-0.16	-0.08	-0.06	-0.12	-0.38	-0.13	-0.53	-0.33	-0.96	-0.04
Spain	0.00	0.11	0.10	0.11	-0.16	0.03	0.11	-0.09	-0.16	0.83
Sweden	-0.06	-0.08	0.05	0.05	0.00	-0.04	0.03	-0.22	0.18	0.32
Turkey	-0.02	0.04	0.04	0.27	-0.06	0.02	0.02	-0.11	-0.32	0.09
UK	0.08	0.17	0.18	0.15	0.07	0.05	0.13	0.00	-0.32	0.21
ROW	-0.09	0.00	-0.05	-0.09	-0.13	-0.06	-0.10	-1.30	-1.49	1.09

Table 11: % Change in Imports Part C

	Nether.	New Zeal.	Norway	Portugal	South A.	Spain	Sweden	Turkey	UK	ROW
Argentina	0.28	0.15	0.21	0.31	1.05	0.27	0.46	0.40	0.34	0.31
Australia	0.21	0.24	0.47	0.32	0.76	0.23	0.34	0.30	0.33	0.46

Austria	0.02	-0.15	-0.03	0.22	0.64	0.12	0.12	0.11	0.05	0.09
Brazil	0.74	0.23	0.29	0.23	0.77	0.28	0.39	0.41	0.38	0.51
Canada	-0.67	-0.46	-1.79	-0.58	-0.31	-0.23	-0.09	-1.01	-0.74	-1.43
Chile	-0.17	-0.10	0.07	-0.41	-0.29	-0.09	0.14	-0.13	-0.43	-0.32
China	0.15	0.16	0.23	0.31	1.05	0.17	0.24	0.32	0.21	0.35
Denmark	0.05	0.04	0.22	0.09	0.35	0.07	0.16	0.11	0.06	0.15
Finland	-0.01	-0.01	0.05	0.00	0.52	0.03	0.08	0.07	0.02	0.06
France	0.10	0.09	0.22	0.14	0.68	0.12	0.17	0.17	0.14	0.14
Germany	0.13	0.04	0.09	0.18	0.47	0.17	0.12	0.20	0.07	0.14
Greece	-0.01	-0.03	0.13	0.02	0.49	0.02	0.06	0.07	0.01	0.05
Hungary	0.07	0.20	0.19	0.16	0.20	0.12	0.15	0.18	0.07	0.21
India	0.16	0.00	0.27	0.11	0.24	0.13	0.18	0.16	0.01	0.07
Indonesia	0.06	0.12	0.15	0.20	0.95	0.08	0.12	0.05	0.03	0.08
Ireland	0.11	0.08	0.34	0.30	0.83	0.20	0.41	0.28	0.09	0.20
Italy	0.03	0.06	0.19	0.09	0.46	0.05	0.09	0.09	0.02	0.09
Japan	0.19	0.10	0.17	0.33	0.32	0.13	0.26	0.27	0.22	0.08
Korea	0.19	0.17	0.28	0.30	1.01	0.14	0.36	0.64	0.19	0.22
Mexico	0.71	-0.14	0.21	0.39	0.34	0.97	0.86	0.92	0.95	0.91
Netherlands	0.00	0.05	0.19	0.09	0.62	0.09	0.21	0.16	0.14	0.19
New Zealand	0.14	0.00	0.18	0.17	0.63	0.21	0.22	0.21	0.13	0.23
Norway	0.04	-0.08	0.00	0.07	0.68	0.19	0.13	0.13	-0.05	0.02
Portugal	0.16	0.15	0.20	0.00	0.54	0.08	0.15	0.11	0.25	0.16
South Africa	-0.29	-0.34	-0.20	-0.10	0.00	-0.01	0.15	-0.50	-0.20	-0.88
Spain	0.10	0.02	0.15	0.10	0.62	0.00	0.17	0.11	0.10	0.06
Sweden	-0.04	0.00	0.04	0.05	0.47	0.06	0.00	0.16	-0.04	0.08
Turkey	0.04	-0.02	0.17	0.05	0.30	0.04	0.22	0.00	0.01	0.05

UK	0.09	0.04	0.25	0.18	0.66	0.14	0.21	0.25	0.00	0.18
ROW	-0.14	-0.09	0.05	-0.02	0.40	-0.04	0.02	-0.14	-0.23	0.00

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ACADEMIC VITA

Isaac Pautz

EDUCATION

The Pennsylvania State University: University Park State College, PA
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Bachelor of Science in Economics, Schreyer Honors College
Relevant Coursework:
- Econometrics
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- Linear Algebra
- Stochastic Modeling
- Combinatorics
- Differential Equations
- Multivariable Calculus

Activities and Achievements
- PSU Economics Association, Math Club, Table Tennis Club, Penn State Jazz Club
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EXPERIENCE

Research Experience
Research Assistant, The Pennsylvania State University, Dr. Eli Byrne Summer 2017
- Revised mathematical proofs and researched social dilemma models in game theory

Work Experience
Tutoring Calculus I and Calculus II 2015-2016
- Assisted students with foundational calculus understanding, homework, and exam preparation

SKILLS

Computer
- Basic proficiency in STATA, R, and Python
- Proficient with Microsoft Excel and Microsoft Word