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APPLYING GAME THEORY TO INTERNATIONAL RELATIONS- THE CASE OF US-SAUDI ARABIA CRUDE OIL PRICE WAR & US-CHINA TRADE WAR

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ABSTRACT

We look at two specific recent events involving international relations and investigate, with the help of game theory, how certain preferences have caused and/or magnified the end outcome of these international relation events. The events that were chosen for analysis was the oil price war between Saudi Arabia and the United States from 2014 to 2016 and the China-United States Trade War from 2018 onwards. The primary objectives of this study was to utilize the core aspects of game theory analysis to understand whether the expectations of these countries match with actual outcome in the real world and to understand how these expectations were established to help certain countries in resolving their bilateral problems.

Keywords: Saudi Arabia, Crude Oil, United States, China, Trade War, Prisoner's Dilemma

1. Introduction

Some of the most complex and complicated problems in global politics and international relations exist at the nexus between international trade, development, and environment. While globalisation has made countries ever more interdependent, the capacity of the international system to deal with global quandaries remains limited. A wide range of global issues still await efficient international solutions - from the depletion of natural resources and global climate change to the creation of an effective and fair-trading system and the elimination of poverty. In attempts to edify their position on a global platform, countries often tweak their relations with their trading partners and plunge into a trade war.

Trade, finance, credit, and monetary policy inevitably transcend national borders globally. The world economy is one integrated whole. A policy or trade related measure adopted by any one country will inevitably have repercussions on others. Only effective and coordinated cooperative action, including steps that need to be taken by inter-governmental authorities, will help to

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

provide the necessary equilibrium. This insinuates the role of specific economic agreements and/or policies in determining the date of a bilateral relationship.

Based on the above implication, two events have been chosen, where certain economic factors played a pivotal role in transmuting the bilateral relations between the involved nations. These events are the Saudi Arabia and United States oil price war, from 2014 to 2016, and the trade/tariff war between United States and China, from 2018 onwards. For the former, it has been assumed that crude oil is a significant determinant in influencing the presented relationship, while the latter looks at how the implementation of tariffs coincided with increased straining of international relations between the nations involved.

Consequently, this paper would utilize such an understanding and illustrate how the fundamentals of game theory can help in explaining the expectations of these countries, with respect to their decision to not alter the economic factor or make adjustments to it. Additionally, we compare such expectations with reality, and see the similarities and discrepancies between the two scenario sets.

2. Literature Review

Stone (2001) describes the extensive and normal presentations of payoffs for a sequential game. This was done by considering the example of a game of chicken, where there are multiple Nash equilibria. The representation of the extensive form of the game involved illustrating these payoffs in a tree diagram, while also understanding, through this depiction, how can a reader discern for the presence of a first mover advantage. Additionally, he segregated the normal form of a game based on the type of the game, by stating that the matrix-form representation of payoffs for simultaneous and sequential games are discordant, where the latter's payoffs and strategies are made by considering the tree diagram.

Nictia (2019) explored the possibility of the existence of trade diversion as direct result of the trade war engaged between United States and China in 2018. Firstly, he discussed about the impact of the tariffs imposed by the US on their own imports. Additionally, by finding out that the exports from China to US decreased since the initiation of this situation, he investigated for the impacts of trade diversion, from US' point of view. The results showed that Taiwan, Vietnam, Mexico, and the European Union were the major beneficiaries, at the expense of China's export losses with the US. Finally, they postulate that while such an offsetting trade impact exists, it is not enough to reverse the lose-all situation that both countries have embroiled themselves into.

Bekkers and Schroeter (2020) provided an economic analysis to the trade war ensuing between United States and China since 2018, with a primary focus on the role of trade diversion and

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

bilateral trade relationsbecause of this conflict. They emphasized on a deterioration of economic and geopolitical relations between the two nations, and how the former is accentuated by the reduction in trade between US and China in 2018 and 2019. A consequence of this is the trade diversion, specifically to East Asian countries, and how this has coincided with a restructuring of value chains in that region.However, due to macroeconomic difficulties in China, it meant that their trend of trade diversion was different from what was experienced in US, and this could be one of the reasons for the Phase 1 agreement in accordance to the terms of the United States.

3. Saudi Arabia and United States Oil Price War: 2014-2016

A. Background

US has been allies with Saudi Arabia for a long period of time, with their relationship dating back to 1936, when Texaco partnered with Saudi Arabia to create what is now Aramco. Since 1979, when the 1979 Islamic revolution in Iran left US' relationship with this country in tatters, it left Saudi Arabia as the primary ally for the western nation. Their relationship has been based on the implicit agreement that United States would provide military protection to the country, in exchange for allowing companies in United States to continue producing crude oil in the region. This agreement has been there since the 1970s and came under threat in 2014.US had put Saudi Arabia under pressure to curb their production, in order to maintain price stability. However, at that time, the middle eastern country's oil minister, Ali al-Naimi, convinced OPEC to augment their production at a rapid rate, in a bid to remove high-cost producers, which were mainly US shale oil producers, out of the market.

One of the reasons for Saudi Arabia to take such an aggressive action against one of its allies was because it was realizing that this relationship was becoming less significant, in the eyes of United States. This was signified by their trend to continue increasing their domestic production of shale oil and meant that their reliance on Saudi Arabia was diminishing. Hence, to restore the significance of the relationship, Saudi Arabia wanted to restore the implicit agreement, and this could only happen if US were forced to desire for oil through external sources. The intention of Saudi Arabia was to drive prices so low that it would bankrupt crude oil related companies in US, and, hence, they would be able to capture the market share previously occupied by US companies. They believed that this would be "a matter of months" due to the high cost of production, especially for shale production, for the US.

Hence, we initially use the profits earned from producing crude oil, by both nations, to see how such a commodity helps to explain the intricacies present in this bilateral relationship, and its impact on the deteriorating association during the era of the Obama administration.

B. The Game

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

I. Model 1: Expectation of Results According to Saudi Arabia

First, we assume that there are two players present: Saudi Arabia and United States. Their payoffs can be represented by the profits that they would attain from engaging in their respective strategies.The mode of decision making would be simultaneous, while their preferences would be ranked in descendingorder of payoffs received from respective strategies. For this game, we assume that there is complete information and players employ pure strategies.

We tried to find a Cournot equation by utilizing historical values, from 2010 to 2016, but found statistical insignificance for the equation[1]:

Regression Statistics				
Multiple R	0.640423612			
R Square	0.410142402			
Adjusted R Square	0.115213603			
Standard Error	21.85818012			
Observations	7			
ANOVA				
	df	*SS*	*MS*	*F*
Regression	2	1328.848545	664.4242725	1.390648874
Residual	4	1911.120153	477.7800383	
Total	6	3239.968698		
	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	130.1847052	162.6056146	0.800616298	0.468208282
Daily Oil production in United States	-7.57956E-06	7.04127E-06	-1.076447751	0.342320811
Daily Oil production in Saudi Arabia	2.27213E-06	1.88284E-05	0.120676059	0.9097665

Hence, to determine the effect of one country's production patterns on world crude oil prices, we determine three Cournot equations, with each equation representing the Cournot equation for that particular year. Since the price war waged on for three years, in calendar year terms, we have tried to create three Cournot equations. This will help us to find a uniform average Cournot equation[2] that can help in explaining the effect of Saudi Arabia's and United States' crude oil production patterns on the price of the commodity.

The derived Cournot equation is as follows:

[1]An implicit assumption of rational expectations is made here, for the years 2014 to 2016, given how the games have been formulated

[2]The derivation of this equation is shown in Appendix A

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

$$P = 860.6629666 - 0.000025487708 15Q_{US} - 0.000040519829 72Q_{SA}$$

To consider costs that each player faces, we account for the marginal production of a barrel of crude oil. For Saudi Arabia, their marginal cost of production is $3[3]. For United States, they have two different marginal production costs- for two different methods of producing crude oil. These are shale production and deep-water production. The cost of the latter method is $57, while the former is $73.

We formulate the game in the format in which Saudi Arabia were expecting to drive away US' production. This game is as follows[4]:

	Player 2 (Saudi Arabia)		
Player 1 (United States)		Maintain Production	Increase Production
	Maintain Production	**-5837241.681**, **703171212.7**	**-504636345.5,** 236191780.1
	Increase Production	-356353799**,** **397981395.3**	-895672732.5, -94485745.44

The above game represents the expected results from engaging in an oil price war. In this game, the Nash equilibrium arises when both countries maintain their production of oil. This is because both have a dominant and dominating strategy of maintaining production levels, rather than increasing the amount of oil barrels produced in a day. This is because the loss for each country, in terms of price falls, is greater than the gain received by raising their daily production levels.Ideally, it does not make sense for either country to increase their productions in the short run as it would lead to incurring of losses for both nations. However, one aspect that is missing from this game is the potential gains that Saudi Arabia were expecting to receive by engaging in the price war. Saudi Arabia were expecting losses in the short run, but wanted to capture US' market share, meaning that their objective was based on the long run. This game only represents the "rational" expectations of Saudi Arabia in the short term.

At this point, United States was a fledgling player in the crude oil market but was still not considered to be a competitor to the main OPEC producers, like Saudi Arabia and Venezuela, in

[3]These figures are updated until 2014

[4]Refer to Appendix B for derivation

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

terms of having a majority market share. With the beginning of the decimation of Venezuela, as a fiscally responsible country, since 2013, with the election of Nicolas Maduro as president, it meant that the Middle Eastern country was the de facto leader of the oil market.

During this time, their role in the market was more of a price setter, through their production patterns, rather than a price taker, insinuating their market power. They had seen United States as an up-and-coming competitor and wanted to engage in the oil price war to ensure that US is kicked out of the crude oil market. Additionally, this was one of the last opportunities available for Saudi Arabia to ensure that United States would feel like needing the country. Relationships had started to become fractured, and US' increasing production of oil was a sign, to Saudi Arabia, that this bilateral relationship was becoming more meaningless to the western country.By ensuring that US are "kicked out" of the oil market, it would mean that US would again depend on foreign sources for oil, and Saudi Arabia would benefit from such an event[5].

Hence, Saudi Arabia would have wanted to increase their oil production, so that oil prices become so depressed that it becomes unfeasible for US producers to manufacture oil, and it would result in Riyadh receiving its bargaining tool back, in terms of dictating bilateral relations with Washington DC. Therefore, the dominant strategy, practically, for Saudi Arabia should be to increase oil production.

We can represent this situation by using a different payoff function for each player, which is that each player is concerned about market share. This is true for the case of Saudi Arabia and US in reality and is a far better explanation of these players expected strategies in the long run.

The payoffs for each player, adjusted for the aim of maximizing market share, is shown below[6]:

	Player 2 (Saudi Arabia)		
Player 1 (United States)		Maintain Production	Increase Production
	Maintain Production	13.04690136%, 12.93442807%	12.35225216%, **17.57001384%**
	Increase Production	**17.67649878%**, 12.24576722%	**16.78293398%, 16.68183197%**

[5]There has been an implicit agreement since the late 1970s that US will supply security equipment to Saudi Arabia, in exchanging for receiving crude oil from the Middle Eastern nation

[6]Refer to Appendix C

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

The above game represents a dominant and dominating strategy of increasing oil production, for both players, which leads to the Nash equilibrium of both players increasing production. Although a desultory number of increase of barrels per day was considered here, but the result should still remain the same for any arbitrary increase in oil production by both nations.

This model is a more accurate representation of the strategies implemented by these nations in reality. Saudi Arabia wanted to increase oil production so that it would become economically unfeasible for United States to produce oil, while restoring one of their major bargaining tools over the western nation.

Meanwhile, US wanted to decrease their oil dependence on Middle Eastern countries, as relations between countries of this region had deteriorated over the last decade, at that time. Hence, through the emergence of shale oil production, US had overtaken Saudi Arabia, in 2014, as the world's largest producer of oil in the world. The only way for them to achieve this objective was to increase production and capture more of the global crude oil market.

From Saudi Arabia's point of view, US cannot manage to maintain their dominant strategy of increasing production due to significantly higher comparative costs. Hence, they would decide, if they were rational, to cut their losses and continue importing oil from them. However, what Saudi Arabia failed to consider was that US was not left with this strategy as well. This led to both nations ending up maintaining their production of oil in 2016, as it had caused Saudi Arabia more damage than US, mainly due to a lack of eclectic consideration of their rival's strategies. This will be discussed further later on.

Hence, this analysis shows that if a country has strategies based on commodities, then there are different methods to show the feasibility of their plans, given their rivals' actions, for different time horizons. If players are focused solely on short run, then a game can be made by making revenues or profits as the mode of payoff. However, if players are more long-term oriented, then market share would be a more apt representation of payoffs.

II. Model 2: Sequential Game

An argument can be made that, actually, this game is a sequential game. Since 2008, the increase of oil production in US has been a general trend andwasn't initiated on the basis of one publicly announced policy/strategy. However, Saudi Arabia had refused to budge on their stance to let prices fall down more, during an OPEC meeting in November 2014. This was a signal to the market Saudi Arabia wants prices to be depressed, in order to make US producers go out of business. This signalling can be considered as a first movement between the two players andserves as the basis to investigate the difference in results obtained by assuming this situation to be sequential.

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

We see this by assuming that Saudi Arabia are the first mover in the market and have already committed to increasing their crude oil production by an arbitrary number, say 1 million barrels a day. So, they are producing around 12.974 million barrels a day, when this adjustment is made.

Based on this information, by using the second stage of the Stackelberg model, the following numbers are derived[7]:

$Q_{US} = 5118255.017$

$P = 204.5061057$

$\prod_{SA} = \$2614340215$

$\prod_{US} = \$673081785.3$

The above situation represents how Saudi Arabia's decision to increase its production has forced US to reduce its production[8], in order to maintain some level of profitability. Theoretically, these calculations indicate a first mover advantage for Saudi Arabia. This is because US' production of oil is lower than what has been seen on average empirically, where they produced 12.31 million barrels per day during this period. Hence, these calculations indicate how it makes sense for Saudi Arabia to continue to increase production if they continue to be the first movers in the oil market, assuming all other factors to be constant.

However, since these calculations are conducted in such a way as to maximize profits, it means that US would have to either reduce production, lose market share and increase their profitability; or increase production, but become harder to conduct operations in the future if competition isn't shooed away from the market. Hence, we see a positive profit in the theoretical calculations, as it assumes that US wants to maximize their profits, rather than having ulterior motives, such as gaining more market share. Hence, these results may indicate the reason why Saudi Arabia initiated such an aggressive move in reality, the numbers for US' proceeds from crude oil should be taken with a grain of salt due to the different motives between such calculations and reality.

To make this sequential game more accurate, a tree game can be constructed to indicate how would the market share changes if any country looks to increase production of crude oil. The construction of this representation is as follows[9]:

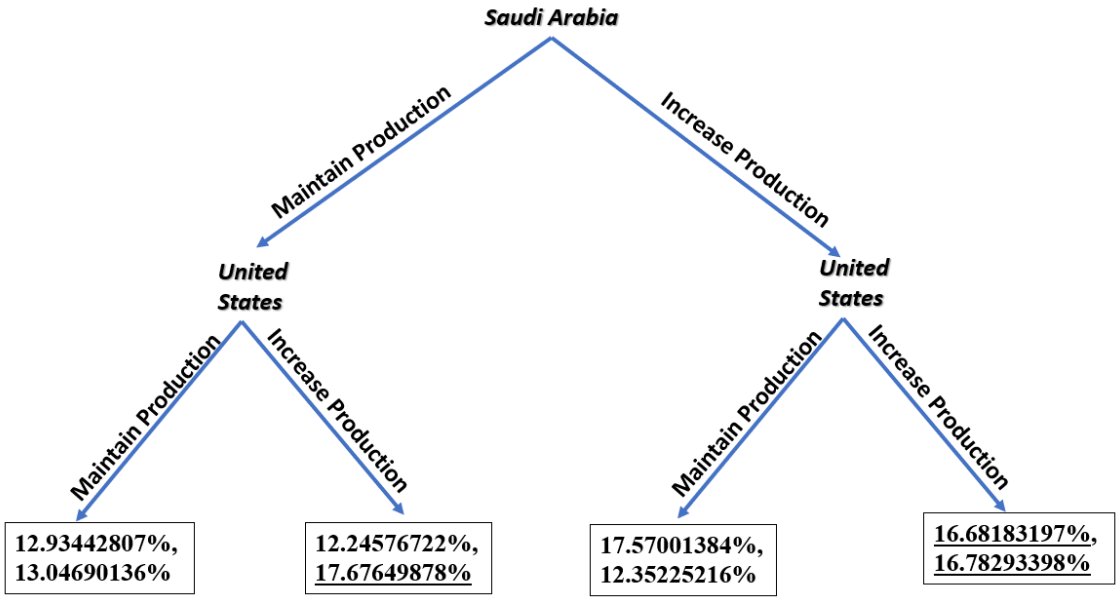
[7]Refer to Appendix D

[8]Comparative to the average production of oil by US in this period calculated before

[9]Note that the payoffs, in terms of market share, would involve the same working irrespective of whether it is simultaneous or sequential in this case

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"



The underlined figures represent the subgame-perfect-equilibrium (SPE). For the games of United States, their subgame equilibrium strategy is increasing the production of crude oil. Then, when considering Saudi Arabia's actions, they would also pick increasing crude oil production, as it offers them the highest payoffs. Formally, increasing production of crude oil by both nations is the unique subgame perfect equilibrium, if market share is considered as the mode of payoffs.

Stone (2001) defines the normal form and extensive form of a simultaneous game to depict similar strategic situations. However, the normal form of a sequential game is different from the regular normal form, and the former should account for the sequential movement of players. Hence, the normal form of this sequential game is as follows:

	United States				
Saudi Arabia		Maintain, Maintain	Maintain, Increase	Increase, Maintain	Increase, Increase
	Increase	**17.5700138%**, 12.3522522%	**17.5700138%**, 12.3522522%	**16.6818320%**, **16.7829340%**	**16.6818320%**, **16.7829340%**
	Maintain	12.9344281%, 13.0469014%	12.2457672%, **17.6764988%**	12.9344281%, 13.0469014%	12.2457672%, **17.6764988%**

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

In the above normal form, the set of Nash equilibriums are Increase, Increase & Maintain and Increase, Increase& Increase.The Nash equilibrium is Increase, Increase & Maintain is based on a non-credible threat, meaning that Increase, Increase & Increase is the pure strategy Nash equilibria.

The tree diagram and normal form of the simultaneous gameare more indicative of what happened in reality, but this time, explained through the lens of a sequential game. Saudi Arabia wanted to increase production to gain more market share in the crude oil, while simultaneously driving US out of the market. Meanwhile, US responded by increasing production as well as they were more concerned with increasing their market share than profitability. This is primarily due to the belief, and reality, that US would significantly their production costs of oil, in order to make such production sustainable in the long run. This had a major effect on Saudi Arabia and is discussed in the next section.

III. Model 3: The Endgame in Simultaneous Mode of Decision-Making

In reality, shale producers were able to cut down on their costs, while the cost of production for Saudi Arabia didn't change. This meant that Saudi Arabia were ultimately not able to drive away US competition, and, in fact, made US a stronger competitor in the crude oil market due to these series of actions.

We model a game that would indicate how the oil price war evolved as time progressed, i.e. see how the endgame differs from the game initially expected by Saudi Arabia. All the components of this game are the same as what was considered for model 1 for this situation, but the only difference would be the value of payoffs received by both countries, while numbers taken for calculation of payoffs would be solely from 2016.

The difference in the value of the payoffs would be seen solely through differences in costs of crude oil production from United States. By 2016, the production costs of US shale and non-shale had drastically reduced to $5.15 and $5.85, respectively.This allowed them to be more competitive, in the global crude oil markets, while they could withstand large drops in oil prices and still manage to make moderate profits.

The payoffs for this game are as follows[10]:

	Player 2 (Saudi Arabia)

[10]Refer to Appendix E for derivation of payoffs for this game

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

Player 1 (United States)		Maintain Production	Increase Production
	Maintain Production	**464359325.4**, **499046871.8**	**-36020051.77**, -3935714.318
	Increase Production	162200160.5, **182846364.4**	-378699046.4, -345623929.8

Because of the cost-cutting measure conducted mainly by US shale producers, but also by non-shale producers in the country, their losses incurred from increasing production would be reined in significantly. This changes the Nash equilibrium from (I, M) in model 1 to (M, M) in this model. This emphasizes that engaging in an oil price war, especially given the reduced costs of producing crude oil, with US is not advisable for Saudi Arabia.

For the endgame, we have taken the mode of payoffs as revenues, and not market share, as Saudi Arabia were struggling to maintain their preferred strategy of cutting down oil prices, and had to start thinking about the domestic economic implications, as the budget surplus had started to reverse, while majority of the economy was supported through oil revenues, which was rapidly decreasing as oil prices dwindled. Additionally, since US had drastically decreased their cost of production, they also insinuated a focus more towards maintaining profitability, as the years progressed.

This result was seen empirically as well, as Saudi Arabia decided to reduce overproduction of crude oil, as their economic status had been jeopardized. They were able to finance this overproduction through record-high budget surplus earned in the early 2010s. However, by late 2015, the country had a record-high budget deficit of $98 billion. The situation was so dire that the country's deputy economic minister at that time, Mohamed Al Tuwaijri, stated in 2016 that if they did not take reform measures then, then they were bound to be bankrupt in 3-4 years.

IV. Closing Comments

The above models have showcased how game theory aided in representing US' reducing dependence on Saudi Arabia, in diplomatic and economic terms. US' main need from Saudi Arabia was oil, and their continued burgeoning production of oil serves as a symbol to indicate that United States' relationship with Saudi Arabia is not as important as it once used to be. Saudi Arabia tried to gain bargaining power by entering into an oil price war with US, in order to gain some bargaining power and enable the restart of more supportive diplomatic relations between the two nations. However, US' oil producers managed to drastically reduce their expensive

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

means of producing shale oil, while Saudi Arabia's budget surplus was rapidly turning into a record budget deficit. This ultimately led to both sides calling a truce, in the oil market, and implied the continued straining of relations, tillthe Obama administration.

The example used here exemplifies how countries can use their comparative advantages, which in this case was Saudi Arabia's cost-efficient production of oil, to attempt to renegotiate or kickstart bilateral relationships with other nations. In this case, however, the tactic did not work as planned.

3. United States-China Trade War: 2018-Present

The previous international relations scenario has focused specifically on how bilateral associations are determined through a country's focus on specific commodities. In this real-world scenario, there is less focus on commodities as a mode of elucidating international relations.

A. Background

Everyone is aware of the feud between China and United States since the arrival of Donald Trump as the President of United States. The intention of the president is to ensure that China buys more American goods, while also ensuring that the benefits accrued by this bilateral relationship is not one-sided. His method of ensuring his objective was by implementing tariffs on Chinese goods. The Asian countered with retaliatory tariffs, and this has been the trend of the trading relationship between the two countries for the better part of the last two years.

Trump has attempted to hold the Chinese accountable by using tariffs to pass the economic burden onto the Asian country. They have also done the same thing, and the continuous retaliation between the two countries has coincided with the simultaneous fracturing of relationships between the nations. Trump believes that their relationships with China will not improve unless they can show that they can bend a knee to the US also. His utilization of the tariffs is a symbol of the threat that the western country poses if relations sour further, to a point where they may be termed enemies, and the situation could turn out to be not to dissimilar to the Cold War of the 20th century.

Some may say that the introduction of the tariff wars has culminated into this loser-all situation. UNCTAD published a paper which emphasized on this statement, explaining that such decisions would lead to decline in bilateral trade and higher prices for consumers in these economies. However, the country that stays in the ring the longest could well decide the question of the ultimate economic superpower of the world.

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

Hence, we try to represent how the US-China bilateral relationship has progressed since 2018 through determining the effect of tariffs in hampering the economic trade agreements between both the nations. Since the implementation of tariffs by both nations coincided with increased strained bilateral associations, we see the prevalence of tariffs in explaining how this relationship has progressed in the two years since this strategy has been initiated.

B. The Game

I. Model 1: Simultaneous Game of Trade War

In this game, we examine the potential benefits of waging a tariff war from both countries' point of view. Firstly, we assume that the decision-making process is simultaneous and that there is complete information present for both players, i.e. United States and China. The game is assumed to be simultaneous to help represent this situation ultimately as a repeated games, in the later sections.

The following game that will be producedconsists of two strategies that each country is presented with:

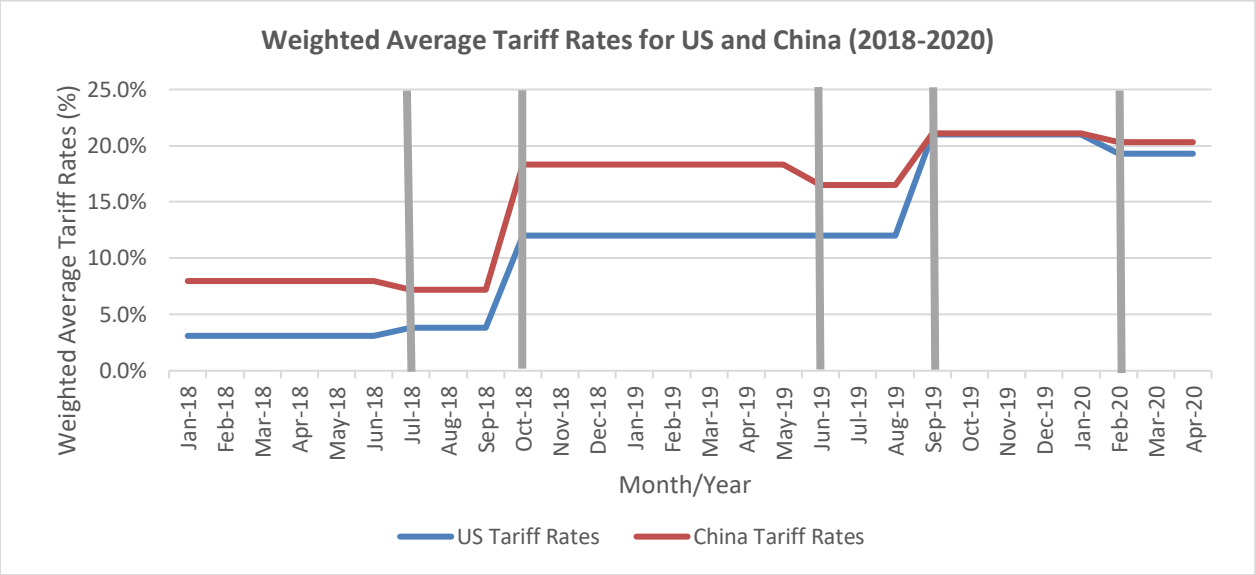
1. Maintain current trading pattern, i.e. free trade agreement
2. Impose tariffs, thereby ditching the free trade agreement

To represent the payoffs that each player receives from their strategy, given what the other player elects, we utilize historical trade balance data to understand the expectations of the tariffs from each country.Hence, we utilize trade balance data from 2010 to 2016[11] to comprehend the expected payoffs from both countries.Therefore, we are trying to establish the expectations from waging the tariff war, from both countries' viewpoint, and seeing whether the resultant findings derived match what happened practically. Also, since we look at the trade balance between US and China, this game would take the shape of a zero-sum game.

[11]Assume a ten-year period as an adequate time horizon to understand the effects of free trade agreement. We didn't include 2008 and 2009 as countries were still reeling from the Financial Crisis of 2008, while years after 2016 is not taken as we are looking at how Trump would expect his strategy would work, so any trade balance data beyond January 2017 won't be used in calculations

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"



Source: Peterson Institute for International Economics

We have used an infographic from the Peterson Institute for International Economics, which divides the US-China tariff war into five stages, with five different average tariff rates[12] incorporated by both countries. The grey arrow represents the starting month of a particular stage of this event. The tariff rates in these stages for each player are as follows:

Stage (Duration of Stage)	United States' Weighted Average Tariff Rate	China's Weighted Average Tariff Rate
Stage 1 (January 2018- June 2018)	3.1%	8.0%
Stage 2 (July 2018- September 2018)	3.8%	7.2%
Stage 3 (October 2018- May 2019)	12.0%	18.3%
Stage 4 (June 2019- August	12.0%	16.5%

[12]We don't consider the last set of tariffs as those were implemented in expectation of normal economic conditions, but the imposition of lockdown andCovid-19 pandemic meant that it would be inaccurate to base the effect of these tariffs in abnormal situations

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

2019)		
Stage 5 (September 2019-January 2020)	21.0%	21.1%

Hence, we will create five games, to understand how the expectations of both countries evolve as time progresses. The tariffs, as enumerated by the infographic, would provide the degree to which a country gains or losses from changing their trading strategy.

Firstly, we consider the stage 1, which was from January 2018 to June 2018.To calculate the payoffs, first we determine the average trade balance from 2010 to 2016. Then, we introduce the strategy of tariffs into the game and discern the expected preferred strategy by both countries. When a tariff is implemented, the country implementing the tariff is expected to gain by the percentage tariff implemented as they are making it more expensive to import goods, which would boost the trade balance of the implementing country, while the country that is facing the tariff would lose the equivalent percentage amount gained by the former country. If both nations implement a tariff, then the impact would be dependent on the net tariff percentage implemented by both countries[13].

The following table represents the payoffs from the game[14]:

Billions of US Dollars Per Month	Player 2 (China)		
Player 1 (United States)		No Tariffs	Tariffs
	No Tariffs	-236.9303333, 309.1454023	-251.7871237, **324.0021926**
	Tariffs	**-231.3464281**, 303.5614971	**-246.0301174, 318.2451863**

[13]If the tariff implemented is set at a higher rate than the tariff faced, then this country would gain, at the expense of the other country

[14]Refer to Appendix F for derivation

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

The above table indicates the presence of Nash equilibrium, i.e. for both countries to implement tariffs. This exists as both countries have a dominant strategy of utilizing tariffs, while the payoffs of executing a no tariffs trade agreement are inferior to the returns from engaging in tariffs. The latter statement indicates that the strategy of tariffs dominates the strategy of no tariffs for both countries. Empirically, this was the outcome that occurred, as both countries continued their aggressive policies, with the aim of maximizing their payoffs.

If we compare the Nash equilibrium to the point where both countries engage in no tariffs strategy, which was the main policy employed in the early and mid-2010s, it indicates that China is benefitting from this policy, as shown by their greater comparative trade balance with US. This is becausethey have employed the higher tariff rate, relative to US.In reality, we see the trade balance worsening for US, from a deficit of $160696.6229 million in 2016 to $185757.3625 million in 2018. Therefore, in the simplest sense, the expectations, as shown by the game, matched what happened practically in the first stage of this trade war.

Next, the below table represents the payoffs from the second stage of the trade war, which spanned from July 2018 to September 2018[15]:

Billions of US Dollars Per Month	Player 2 (China)		
Player 1 (United States)		No Tariffs	Tariffs
	No Tariffs	-118.4651667, 154.5727011	-125.1507223, **161.2582568**
	Tariffs	**-115.0658529**, 151.1733873	**-121.6222346**, **157.7297691**

The implications of the above game are similar to that of the first stage of the trade war: dominant strategy and dominating strategy for nations is to employ tariffs. In terms of relating expectations to reality, this model captures the strategies employed by the nations in reality. Additionally, the manner in which these strategies are employed continues to benefit China, which is shown by the model and empirically. Theoretically, the payoffs of China have improved, relative to the situation where no tariffs are used by either country, at the expense of

[15]Refer to Appendix G for derivation

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

US, while practically, China's trade balance with US improved, from $96657.82302 million in 2016 to $115723.2831 million in 2018.

Hence, we can see a pattern being formed, when considering each stage of the trade war. As long as China's tariff rates remain above US', then China would remain comparatively better off, and this would come at the expense of US. To confirm this hypothesis, we derive the games for the remaining three stages, where the tariff rates of China are always, on average, higher than US'.

Payoffs for stage 3, which was from October 2018 to May 2019[16]:

Billions of US Dollars Per Month	Player 2 (China)		
Player 1 (United States)		No Tariffs	Tariffs
	No Tariffs	-314.38475, 434.8135199	-360.6356278, **481.0643977**
	Tariffs	**-287.3057817**, 407.7345516	**-330.3071834, 450.7359532**

Payoffs for stage 4[17], which was from June 2019 to August 2019[18][15]:

Billions of US Dollars Per Month	Player 2 (China)		
Player 1 (United States)		No Tariffs	Tariffs
	No Tariffs	-117.55175, 168.1444912	-133.3800777, **183.9728189**

[16]Refer to Appendix H for derivation

[17]For the sake of simplicity, we keep the duration of the tariffs for both countries as the same

[18]Refer to Appendix I for derivation

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

	Tariffs	**-107.2736152**, 157.8663564	**-121.8685666**, **172.4613079**

Payoffs for stage 5, which spanned from September 2019 to January 2020[19]:

Billions of US Dollars Per Month	Player 2 (China)		
Player 1 (United States)		No Tariffs	Tariffs
	No Tariffs	-195.6151111, 284.7647488	-229.5664608, **314.2107061**
	Tariffs	**-167.6891253**, 256.8387629	**-195.776018**, **284.9256556**

The above games, which represent payoffs at different stages of the trade war, provide the same implications as what was seen for stage 1 and stage 2. This means that utilizing tariffs has always been a dominant strategy for both countries since the trade war began, as they have no incentive deviate from this position. This is tantamount to what has been observable between the two nations over the last couple of years.

Also, this implies that the expectation was that China would be better off, in terms of trade balance. Initially, this had panned out as expected by the models, but this was not the case in the long run. In 2019, the trade balance had increased for US by $73749.7 million year-on-year, with all months in the calendar year of 2019, experiencing less of a trade deficit comparative to 2018.One can argue that the tentative agreement with China to buy up to $50 billion in American farming products could be the reason for this. However, this was seen towards the end of 2019, and can explain, to some degree, the larger-than-average deficit reductions of trade balance for the US from October 2019 onwards. However, this trend was seen throughout the year, and not just at the end of the year.

[19]Refer to Appendix J for derivation

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

A postulation for the decline in trade deficit for US can be that tariffs have caused a significant reduction in trade between the two countries in 2019, and this could have caused trade diversion, to other countries in East Asia that have similar economic appeals as China (Bekkers & Schroeter, 2020). What this means is that trade with other countries would have significantly increased, for US, at the expense of their relationship with China.Comparing the first two quarters of 2019 to 2018, Nicita (2019) found trade diversion effects to equal $21 billion, to offset the loss of import of $35 billion from China. Sectors that witnessed these effects were sectors most affected by this trade war, which are motor vehicles, transport equipment, machinery, and electrical equipment.

However, the trade diversion patterns for China were starkly different, as the fall in imports from US was countered with a fall in imports from other countries. One potential reason for this could be linked to the slowdown of the Chinese economy in 2019, where consumers had a lower demand for imports from any country. Another reason attributed by Bekkers and Schroeter was the restructuring of value chains in East Asia.This is illustrated by noticing the trading patterns of Japan, Vietnam, South Korea, and Taiwan, where they are exporting significantly more to the US, and less to China. Hence, the restructuring of value chains and decrease in demand for imports can be considered as sufficient reasons to understand how China have not been able to build on their trade surplus gains from 2018.

It is likely that China would have viewed these difficulties as reason to re-negotiate the trade deal with the US, as they offer a large market for import and export of goods and services, and gaining greater access to it could help them improve their aggregate demand, which can stimulate growth. Hence, we saw China agree to buy $50 billion of American farm products, along with increasing their imports from US by almost $200 billion over the next couple of years.

II. Model 2:Representation of Game Through Trade Volume

Next, we look at how this game would look like if the mode of payoffs was trade volume. For this case, we cannot make the simple assumption that each player looks to maximize their trade volume, given Trump's anti-trade policies with China. His emphasis was to reduce trade deficit and to increase domestic production. As the former scenario was prevalent, we could readily define the aim of each player in the previous game.

One reason for making this game variation is to understand how this situation can be a lose-lose for both countries. Trade volume is one of the ways which we believe would decrease irrespective of who implements the tariff, hence this would be a loss for both nations involved. In this case, we assume the implementation of tariffs to adversely impact the imports of the

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

implementing nation and the exports of the targeted nation. Hence, there is no consideration of additional tariff revenue earned, due to the nature of the payoffs.

We represent the payoffs in a similar manner to the previous model, where payoffs represent the complete trade volume of both nations, in billions of dollars.

Payoffs for stage 1, which was from January 2018 to June 2019[20]:

Billions of US Dollars Per Month	Player 2 (China)		
Player 1 (United States)		No Tariffs	Tariffs
	No Tariffs	**2596.722667**, **1961.639827**	**2509.322951**, 1900.43633
	Tariffs	2554.121676, **1927.500961**	2466.72196, 1866.297463

Payoffs for stage 2, which was from July 2018 to September 2019[21]:

Billions of US Dollars Per Month	Player 2 (China)		
Player 1 (United States)		No Tariffs	Tariffs
	No Tariffs	**1298.361333**, **980.8199134**	**1258.737955**, 953.0728055
	Tariffs	1272.42713, **960.0371969**	1232.803751, 932.290089

[20]Refer to appendix K for derivation

[21]Refer to appendix L for derivation

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

Payoffs for stage 3, which was from October 2018 to May 2019[22]:

Billions of US Dollars Per Month	Player 2 (China)		
Player 1 (United States)		No Tariffs	Tariffs
	No Tariffs	**3511.553**, **2665.045143**	**3264.265684**, 2492.546247
	Tariffs	3306.592049, **2498.981286**	3059.304733, 2326.48239

Payoffs for stage 4, which was from June 2019 to August 2019[23]:

Billions of US Dollars Per Month	Player 2 (China)		
Player 1 (United States)		No Tariffs	Tariffs
	No Tariffs	**1327.915**, **1010.535138**	**1242.202581**, 950.8808643
	Tariffs	1250.479281, **947.391586**	1164.766862, 887.7373128

Payoffs for stage 5, which spanned from September 2019 to January 2020[24]:

Billions of US	Player 2 (China)

[22]Refer to appendix M for derivation
[23]Refer to appendix N for derivation
[24]Refer to appendix O

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

Dollars Per Month			
Player 1 (United States)		No Tariffs	Tariffs
	No Tariffs	**2223.042889**, **1694.130304**	**2046.417265**, 1571.349077
	Tariffs	2013.159343, **1522.408006**	1836.53372, 1399.626779

What we see from the above payoffs is that, irrespective of the time period, both nations have a dominant and dominating strategy to not implement tariffs, if they aim to maximize their trade volume. Hence, the Nash equilibrium in all the games is for both nations to not implement tariffs. However, we see that, in reality, both nations implement tariffs and that their trade volume is worse for US and China. The latter is shown in the above payoffs, but in this representation of the game, there is no sub-optimal Nash equilibrium.

III. Model 3: Incorporating the Concept of Trade Diversion

In the previous section, we saw how, if countries were looking to maximize their trade volume, then they would prefer to maintain status quo and not implement tariffs. However, this is not what happened in reality, as both nations simultaneously implemented tariffs around the same time period that either nation imposed one on the other nation.

One aspect that was missing from the games incorporating trade volume was the offsetting effect of engaging in this trade war. It is true that both nations would lose a large amount of exports and imports through this protectionist policy, but it also opened up other avenues, more so for the United States. As mentioned before, US was able to offset some of its trade volume loss to China by increasing its trade volume with other nations, specifically with East Asian countries. Although it was not enough to replace China's trade, it was still able to provide US valuable inputs.

In this section, we look to incorporate the idea of trade diversion into this model and see what the value of this should be to ensure that the expectations, as postulated by various articles and papers, matches with reality.

For this, we add a constant to each payoff of both the players, and attempt to derive the conditions that ensure that this is a loser-all situation. In short, we derive the value that these

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

constants need to take that represents this trade war to be an example of Prisoner's Dilemma. Given the earlier discussion about the existence of trade diversion, we postulate that the value of the constants would signify the increase in trade volume with the rest of the world except for China.

The constants would be attached to the tariff strategy for each player. This means that if the constant would only be added to their payoffs if they implement the tariffs on the other nation. Hence, this implies that the implementing nation must be planning to increase their trade volume with other countries in order to offset their trade volume decrease with the other player of the game.

We show the calculations for the first stage of the tariff game and see what the conditions are necessary to make implementing of tariffs a dominating strategy, while ensuring that the game complies with the norms of Prisoner's Dilemma.

Payoffs for stage 1 which was from January 2018 to June 2019,which incorporates the value of the constants as C=62 and US=43[25]:

Billions of US Dollars Per Month	Player 2 (China)		
Player 1 (United States)		No Tariffs	Tariffs
	No Tariffs	2596.722667, 1961.639827	2509.322951, **1962.43633**
	Tariffs	**2597.121676**, 1927.500961	**2509.72196**, **1928.297463**

The above game incorporates the expectations of both the nations, when contemplating about waging a tariff war with each other, and matches it with what was expected by experts, through the inclusion of trade diversion. By including this additional aspect, the tariff war game is now an example of Prisoner's Dilemma, where the equilibrium of both nations implementing tariffs is sub-optimal to the case where both nations do not implement tariffs and maintain free trade.

[25]Refer to Appendix P for derivation of constants' value

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

The following games will exemplify similar derivations and ascertain the value of the constants so that a Prisoner's Dilemma game is achieved. The final games are shown here, while the workings for these can be found in the appendix.

Payoffs for stage 2, which was from July 2018 to September 2019, which incorporates the value of the constants as C=28 and US=26[26]:

Billions of US Dollars Per Month	Player 2 (China)		
Player 1 (United States)		No Tariffs	Tariffs
	No Tariffs	1298.361333, 980.8199134	1258.737955, **981.0728055**
	Tariffs	**1298.42713**, 960.0371969	**1258.803751,** **960.290089**

Payoffs for stage 3, which was from October 2018 to May 2019,which incorporates the value of the constants as C=173 and US=205[27]:

Billions of US Dollars Per Month	Player 2 (China)		
Player 1 (United States)		No Tariffs	Tariffs
	No Tariffs	3511.553, 2665.045143	3264.265684, **2665.546247**
	Tariffs	**3511.592049**, 2498.981286	**3264.304733**, **2499.48239**

[26]Refer to Appendix Q for derivation of constants' value

[27]Refer to Appendix R for derivation of constants' value

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

Payoffs for stage 4[17], which was from June 2019 to August 2019, which incorporates the value of the constants as C=60 and US=78[28]:

Billions of US Dollars Per Month	Player 2 (China)		
Player 1 (United States)		No Tariffs	Tariffs
	No Tariffs	1327.915, 1010.535138	1242.202581, **1010.880864**
	Tariffs	**1328.479281**, 947.391586	**1242.766862,** **947.7373128**

Payoffs for stage 5, which spanned from September 2019 to January 2020, which incorporates the value of the constants as C=123 and US=210[29]:

Billions of US Dollars Per Month	Player 2 (China)		
Player 1 (United States)		No Tariffs	Tariffs
	No Tariffs	2223.042889, 1694.130304	2046.417265, **1694.349077**
	Tariffs	**2223.159343**, 1522.408006	**2046.53372**, **1522.626779**

Given the results of Bekkers & Schroeter (2020) and Nicita (2019), we assumed that these countries would have expected to engage in a strategy that is similar to the one described in this

[28]Refer to Appendix S for derivation of constants' value

[29]Refer to Appendix T for derivation of constants' value

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

sub-section. However, what happened in reality is slightly different from what these models showcase. While the equilibrium is more synonymous with what experts have believed to have occurred over the last couple of years, the concept of trade diversion has not exactly been the same as shown in this model. For US, the model exemplifies what happened actually, but the same cannot be said for China. With a reduction in imports from US for China, this was countered by a decrease in imports from other nations as well. One reason that can be postulated for this is the slowdown of demand amongst Chinese consumers over the last couple of years. This insinuates lower demand for imports. However, when contemplating about such a decision in 2018, the Chinese government were likely to not have considered this as an important factor in their pursuit to win this war. Hence, we assumed that China's expectation from the trade war would be similar to what US expected, in terms of trade diversion, although the outcome of this part was different for both the players. This is the only difference extant between the models presented in this section and in reality.

IV. Model 4: US-China Trade War as A Repeated Game

As described by the Peterson Institute of International Economics, the US-China trade war has, as of the end of 2019, encompassed five stages. Given that the strategies available to both nations insinuate cooperation, in the form of free trade, or to deflect, by implementing tariffs on the other player, this resembles the crux of a repeated game for a finite number of rounds.

In this section, we look at the games from section I and section III and see how the notion of game theory alters the payoffs available to both players. We look at the payoffs available from cooperating and deflecting for both nations, while assuming that both nations follow a grim strategy. This assumption is made based on what happened in reality, as when US first implemented tariffs in January 2018, both nations have continuously stuck to this strategy of deflection for the better part of the last two years.

Based on these conditions, the payoffs, when considering trade deficit of both nations, for the respective strategies are as follows[30]:

$$Cooperation\ Payoffs\ (US) = -982.9471111$$

$$Cooperation\ Payoffs\ (China) = 1351.440863$$

$$Deflection\ (Stage\ 1)\ Payoffs\ (US) = -1000.920431$$

$$Deflection\ (Stage\ 1)\ Payoffs\ (China) = 1389.854878$$

[30]Refer to Appendix U for derivation of payoffs

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

The above figures indicate a clear winner and loser, in terms of trade balance, in this trade war. Since China's trade balance, when combining payoffs from the five stages, improves if it chooses to deflect in the first stage, comparative to payoffs from cooperation, while they gain a short-term benefit of $14.85679 billion by deflecting in the first stage, it insinuates that China would benefit more by deflecting, given the long-term and short-term benefits.

The same does not apply for the case of US, as their trade deficit increases if they deflect, by $17.9733 billion, comparative to if they cooperated for the entirety of the trade war duration. However, they do receive a short-term benefit, as their overall trade balance increases by $5.58391 billion in stage 1. Given how this trade war has move forward practically, it can be said that US decided to pick the short-term benefits, while risking the chance of worsening their trade balance in the long run.

However, this trend was not seen in 2019, as the overall trade balance for US increased, from a deficit of $579.9 billion in 2018 to $576.9 billion in 2019.One of the major reasons for this was US' decreased deficit with China in 2019, as the surplus for the latter nation decreased by $73.7497 in 2019, year-on-year. This result does not match with the expectation depicted above, along with the insinuation that this would be a loser-all scenario. The latter cannot be seen through using trade balance as a mode of payoff, as any changes in this balance between the two countries would always imply a winner and a loser.

Hence, to modify these games to what happened in reality, while also attempting to provide some numeric evidence to the claims of a loser-all scenario, we create a repeated games by utilizing the payoffs from section III of this topic. This game incorporates the idea of Prisoner's Dilemma, which was similar to what was expected to happen, according to several experts, if both nations went all out with their trading strategies. In this scenario, we use the notion of repeated games to see if a similar conclusion from section III is seen here.

Based on these conditions, the payoffs, when considering trade volume of both nations, for the respective strategies are as follows[31]:

$$Cooperation\ Payoffs\ (US) = 10957.59489$$

$$Cooperation\ Payoffs\ (China) = 8312.170324$$

$$Deflection\ (Stage\ 1)\ Payoffs\ (US) = 10409.53074$$

$$Deflection\ (Stage\ 1)\ Payoffs\ (China) = 7892.5729$$

[31]Refer to Appendix V for derivation of payoffs

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

The above payoffs are more representative of the Prisoner's Dilemma situation which people were expecting to occur from this trade war. Although both nations do gain short-term benefits, in the form of increased trade volume in stage 1, this isoffset, in greater proportion, by the long-term loss created by deflecting. In stage 1, by deflecting, US and China gain $0.399 billion and $0.797 billion respectively. However, as seen in reality, this deflection insinuates a grim strategy, where if one player deflects, then the other player also cheats in the next period and will continue to cheat no matter what the other player does in the future.

This deflection meant that they incur relative long-term losses due to deflection in the first stage, comparative to payoffs attained by engaging in free trade through all the stages. US and China would experience a loss $548.064 billion and $419.597 billion, respectively, if they deflect in the first stage.

Given that both nations have, in general, continued to implement tariffs on various different goods, as time has progressed, it indicates that both nations are looking more towards maximizing their short-term benefits, but would be left worse off, when accounting long-term benefits, as it means lower trade volume for both nations if there is no free trade occurring between the two nations. Hence, we see that the notion of repeated games is also apt in explaining the general timeline and outcome of the trade war and how the expected outcomes from engaging in strategies available to them matches to reality, at least according to what experts have pronounced.

The one drawback is that countries would prefer to look at the present value of such trade transactions. However, due to the presence of different interest rates at different periods of time within the stage time horizon itself, we have decided to not calculate the PV of such transactions. In reality, it is likely that countries would account for such calculations before arriving at a fixed conclusion. However, we believe that even if such transactions are discounted by a suitable discounting factor, the conclusion, in terms of the strategy used by each nation and the outcome corresponding from such decisions, would not change, but the magnitude of the conclusion would differ.

V. Closing Comments

In an increasingly fraught US-China relationship, issues of international relations and laws have become extremely important in their own right and illustrative of broader patterns. One of the may salient arenas is trade (and related economic matters). In the field of trade, the Trump-led administration and the Jinping regime have adopted significantly conflicting stances on the content of legal regulations, and the United States has not played its conventional role as principal patron of a law-based, multilateral order. Alongside these similarities are noteworthy contrasts between the field of trade. In trade law and related fields, China under Xi has presented

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

itself as a leading protector of the mostly liberal existing system, notwithstanding a full-fledged and ongoing history of widespread complaints that China does not comply with applicable and existing legal rules. As the United States, under Trump, has turned its back on a legal and institutional order it had long championed, China has been aspiring an option to sustain or undermine the status quo.

Trade measures adopted by the Trump administration, and reactions by targeted states, have escalated the trade wars - something that Trump has declared "good" and "easy to win." China has been the biggest target of Trump's trade measures, including some of the most controversial ones. As the trade war has panned out, the overall trade deficit of US augmented, while the overall surplus of China increased, if they engaged in the equilibrium strategy of implementing tariffs. However, with China's economy slowing down, on account of weak consumer demand, it meant that China could not lose out on market access of its largest trade partner, in terms of volume and surplus. Hence, we saw China committing to importing American goods in late 2019. This gave US the edge, in terms of a definite victor of the trade war,given that China agreed to partially surrender, through this commitment. This was the primary goal of Trump, which is that he wanted China's trade surplus to be reduced, while also engage in fairer trade practices. This commitment ensured at least one of his objectives were starting to be met.

This coincided with friendlier talks, which also involved the discussion about dropping the tariffs. This was bound to happen, given the loser-all situation that had persisted for the duration of the war, as depicted by the models that integrated the concept of trade diversion. The commitment to reduce tariffs may have been more from China, given that they are an export-oriented nation and lower consumer demand was hampering their growth prospects. This may have been something not considered in great detail by the Asian country, and meant that US, who had various trading substitutes for Chinese goods in this period, were relatively better off, although the trade balance for 2018 may suggest otherwise.

One thing that needs to be kept in mind is that Trump's agenda for the trade war is more to make China pay for their "shady" trade practices. This, coupled with increased emphasis on "America First" and boosting domestic production, meant that trade balance and volume were probably not his primary metric to assess the western nation's position in the war.

The models and explanation given for them imply that such a deterioration in relations between the two nations may probably have been caused by a worsening of trade relations due to a tit-for-tat strategy with tariffs. Although this may have been China's method of approach, US' was more eclectic, and aimed to solely make China care more about its own self. The agreement indicates a progression to this attitude, at least temporarily, and this has meant that US has also

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

started to become more receptive to China's ideas, as indicative by the numerous discussion they had in 2019.

4. Conclusion

The paper discusses how certain bilateral relations, at a certain point of time, can be explained by the economic agreements in place between the two nations. For United States and Saudi Arabia, one nation were trying to distance themselves from the other nation, while the other wanted to maintain this relationship and tried to regain bargaining power in the relationship by making themselves more prospective to the other nation. Saudi Arabia tried to engage in an oil price war so that it acts as an enabler to re-engage relations between two countries in the Obama administration, but it backfired horrendously for them, while relations fractured further till the end of the US President's term. For United States and China, both countries had implemented tariffs on several goods over many time periods. US aimed to make China less China-centric and make them care more about how they can help America, while China refuse to budge on the claims of unfair trade practices and that they are focused on themselves only. The tariff war symbolized a straining of relationships between the two nations for the better part of two years.

The utilization of the concepts presented by the subject of game theory helped to illustrate the major considerations that each nation needs to take before actually implementing the action. It helps to indicate how nations may interpret a situation differently, which was shown through a difference in the mode of payoffs considered for each event. They helped to exemplify what expectations would a country have of implementing a particular strategy and what payoffs would they be expecting to receive.

However, one flaw of this type of analysis of international relations is that it only incorporates a limited set of factors that can influence the result of the game. In reality, there are several factors that are considered before taking an action, and this cannot be always represented in a series of games. This is one aspect missing from the analysis of the bilateral relations. Nonetheless, the games constructed give a fairly accurate representation of the kind of major factors that countries consider as part of their strategy. Additionally, as most of the models made in this paper match with what actually happened, the games can serve as an effective tool to understand both the sides in anincreasingly strained bilateral international relationship.

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ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

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ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

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Appendix

Appendix A: Derivation of Cournot Equation for the Saudi Arabia and United States' Production of Crude Oil

$$93.13460414 = \alpha - 11801000\beta_{US} - 11519000\beta_{SA} \quad - Cournot\ Equation\ for\ Year\ 2014$$

$$48.74765171 = \alpha - 12781000\beta_{US} - 11998000\beta_{SA} \quad - Cournot\ Equation\ for\ Year\ 2015$$

$$43.2262511 = \alpha - 12349000\beta_{US} - 12406000\beta_{SA} \quad - Cournot\ Equation\ for\ Year\ 2016$$

Subtracting Cournot Equation for Year 2015 from Cournot Equation for Year 2014:

$$44.38695243 = 980000\beta_{US} + 479000\beta_{SA}$$

$$\beta_{SA} = 0.00009266587146 - 2.045929019\beta_{US} \quad - Equation\ 4$$

Subtracting Cournot Equation for Year 2016 from Cournot Equation for Year 2015:

$$5.52140061 = -432000\beta_{US} + 408000\beta_{SA}$$

Plugging Equation 4 into the above simplified equation:

$$-32.28627495 = -432000\beta_{US} - 834739.0398\beta_{US}$$

$$\therefore \boldsymbol{\beta_{US} = 0.00002548770815}$$

$$\boldsymbol{\beta_{SA} = 0.00004051982972}$$

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

$$\boldsymbol{\alpha = 93.13460414 + (0.00002548770815 \times 11801000) + (0.00004051982972 \times 11519000)}$$

$$\boldsymbol{\therefore \alpha = 860.6629666}$$

$$\boldsymbol{P = 860.6629666 - 0.00002548770815 Q_{US} - 0.00004051982972 Q_{SA}}$$

Appendix B: Derivation of Payoffs for Expectation of Results According to Saudi Arabia

The payoffs are calculated by deriving the profits of each country given the strategies of both the nations. Profits are calculated by the formula of $Price \times Quantity = Quantity \times (Price - Marginal\ Cost)$. For US, there are two aspects of crude oil production: shale oil production and non-shale oil production. We assume that they are sold at the same price but have different marginal costs.

	Player 2 (Saudi Arabia)		
Player 1 (United States)		Maintain Production	Increase Production
	Maintain Production	$(4000000 \times (860.6629666 - 0.02548770815 \times 12310 - 0.04051982972 \times 11974 - 73)) + (8310000 \times (860.6629666 - 0.02548770815 \times 12310 - 0.04051982972 \times 11974 - 57))$, $11974000 \times (860.6629666 - 0.02548770815 \times 12310 - 0.04051982972 \times 11974 - 3)$	$(4000000 \times (860.6629666 - 0.02548770815 \times 12310 - 0.04051982972 \times 12974 - 73)) + (8310000 \times (860.6629666 - 0.02548770815 \times 12310 - 0.04051982972 \times 12974 - 57))$, $12974000 \times (860.6629666 - 0.02548770815 \times 12310 - 0.04051982972 \times 12974 - 3)$

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

	Increase Production	$(5000000 \times (860.6629666 - 0.02548770815 \times 13310 - 0.04051982972 \times 11974 - 73)) + (8310000 \times (860.6629666 - 0.02548770815 \times 13310 - 0.04051982972 \times 11974 - 57))$, $11974000 \times (860.6629666 - 0.02548770815 \times 13310 - 0.04051982972 \times 11974 - 3)$	$(5000000 \times (860.6629666 - 0.02548770815 \times 13310 - 0.04051982972 \times 12974 - 73)) + (8310000 \times (860.6629666 - 0.02548770815 \times 13310 - 0.04051982972 \times 12974 - 57))$, $12974000 \times (860.6629666 - 0.02548770815 \times 13310 - 0.04051982972 \times 12974 - 3)$

$$Average\ Production\ of\ Crude\ Oil\ by\ Saudi\ Arabia = \frac{Production\ Levels_{2014-2016}}{3}$$

$$= 11974000\ barrels\ per\ day$$

$$Average\ Production\ of\ Crude\ Oil\ by\ United\ States = \frac{Production\ Levels_{2014-2016}}{3}$$

$$= 12310000\ barrels\ per\ day$$

Cournot Equation:

$$P = 860.6629666 - 0.00002548770815Q_{US} - 0.00004051982972Q_{SA}$$

Marginal Production Cost of producing shale crude oil for United States: $73

Marginal Production Cost of producing non-shale crude oil for United States: $57

Marginal Production Cost of producing crude oil for Saudi Arabia: $3

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

Assume that both increased their production by 1000000 barrels per day, which is close to the difference between the maximum and minimum number of barrels produced per day by both countries within this period.

Note: As of 2014, US was producing more than 4 million barrels per day, for shale production. For simplicity, shale production is assumed to be 4 million in this table. Also, since the focus of US crude oil production was mainly on shale production during this time horizon, it is assumed that the increase in crude oil production by US is solely through increase in shale production.

Appendix C: Derivation of Payoffs for Expectation of Results According to Saudi Arabia with Market Share as Mode of Payoffs

Assume that each country has the choice to maintain their production or increase their production by 5 million barrels per day. The resultant Nash equilibrium will be the same irrespective of the number of barrels per day that each country wishes to produce additionally.

The daily production of crude oil by both nations at the end of 2014 was 11.6 million barrels for United States and 11.5 million barrels for Saudi Arabia.

	Player 2 (Saudi Arabia)		
Player 1 (United States)		Maintain Production	Increase Production
	Maintain Production	$\frac{11600000}{88910000}$, $\frac{11500000}{88910000}$	$\frac{11600000}{93910000}$, $\frac{16500000}{93910000}$
	Increase Production	$\frac{16600000}{93910000}$, $\frac{11500000}{93910000}$	$\frac{16600000}{98910000}$, $\frac{16500000}{98910000}$

Appendix D: Derivation of Profit Payoffs for Both Nations under Stackelberg Model

It is assumed that the calculation of the first stage, i.e. Saudi Arabia deciding how much to produce, has already been decided, and now, US has to decide their production levels, keeping in mind that such calculations insinuate an emphasis on profit maximization.

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

Assume that from the derivation of the first stage of the Stackelberg model, Saudi Arabia decided to increase their production by 1 million barrels per day, taking their daily production to 12.974 million barrels.

$$P = 860.6629666 - 0.000025487708150Q_{US} - 0.00004051982972(12974000)$$

$$P = 860.6629666 - 0.000025487708150Q_{US} - 526.7577864$$

$$P = 333.9051802 - 0.000025487708150Q_{US}$$

$$\prod_{US} = (P - MC_{US}) \times Q_{US}$$

$$\prod_{US} = (333.9051802 - 0.000025487708150Q_{US} - 73) \times Q_{US}$$

$$\prod_{US} = 260.9051802Q_{US} - 0.000025487708150Q_{US}^2$$

$$\prod'_{US} = 260.9051802 - 0.0000509754163Q_{US}$$

$$Q_{US} = 5118255.017$$

$$P = 204.5061057$$

$$\prod_{SA} = \$2614340215$$

$$\prod_{US} = \$673081785.3$$

Appendix E: Derivation of Payoffs for The Endgame in Simultaneous Mode of Decision-Making

The payoffs are calculated by deriving the profits of each country given the strategies of both the nations. Profits are calculated by the formula of $Price \times Quantity = Quantity(Price - Marginal\ Cost)$. For US, there are two aspects of crude oil production: shale oil production and non-shale oil production. We assume that they are sold at the same price but have different marginal costs.

	Player 2 (Saudi Arabia)		
Player 1 (United States)		Maintain Production	Increase Production
	Maintain Production	$(4000000 \times (860.6629666 - 0.02548770815 \times 12349 - 0.04051982972 \times 12406 - 5.15)) + (8349000 \times$	$(4000000 \times (860.6629666 - 0.02548770815 \times 12349 - 0.04051982972 \times 13406 - 5.15)) + (8349000 \times (860.6629666 -$

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

		$(860.6629666 - 0.02548770815 \times 12349 - 0.04051982972 \times 12406 - 5.85))$, $12406000 \times (860.6629666 - 0.02548770815 \times 12349 - 0.04051982972 \times 12406 - 3)$	$0.02548770815 \times 12349 - 0.04051982972 \times 13406 - 5.85))$, $13406000 \times (860.6629666 - 0.02548770815 \times 12349 - 0.04051982972 \times 13406 - 3)$
	Increase Production	$(5000000 \times (860.6629666 - 0.02548770815 \times 13349 - 0.04051982972 \times 12406 - 5.15)) + (8349000 \times (860.6629666 - 0.02548770815 \times 13349 - 0.04051982972 \times 12406 - 5.85))$, $12406000 \times (860.6629666 - 0.02548770815 \times 13349 - 0.04051982972 \times 12406 - 3)$	$(5000000 \times (860.6629666 - 0.02548770815 \times 13349 - 0.04051982972 \times 13406 - 5.15)) + (8349000 \times (860.6629666 - 0.02548770815 \times 13349 - 0.04051982972 \times 13406 - 5.85))$, $13406000 \times (860.6629666 - 0.02548770815 \times 13349 - 0.04051982972 \times 13406 - 3)$

Daily Production of crude oil (shale and non-shale) by United States in 2016: 12349000 barrels

Daily Production of crude oil by Saudi Arabia in 2016: 12406000 barrels

Marginal Production Cost of producing shale crude oil for United States in 2016: $5.15

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

Marginal Production Cost of producing non-shale crude oil for United States in 2016: $5.85

Marginal Production Cost of producing shale crude oil for Saudi Arabia in 2016: $3

We have assumed the level of shale oil production in United States to be the same level in 2016, comparative to 2014, at 4 million barrels per day.

Appendix F: Derivation of Payoffs for The Simultaneous Game of Trade War for Stage 1

Equations for the trade balance of both nations have been calculated by using historical data from 2010 to 2016, while adding a time trend as well. This assumes that the trend of trade balance for both nations seen from 2010 to 2016 will carry forward in future years as well.

Equation for Trade Balance of US in a Free-Trade Era from 2017 onwards:

$-134.3427929 + 15.95094241(Y - 2016) - 346.8252071 - 12.29727575(Y - 2016)$; Y- Year

The first half of the equation represents the time trend of the trade balance for US from the rest of the world (excluding China) and the second half of the equation represents the trade balance between US and China.

Equation for Trade Balance of China in a Free-Trade Era from 2017 onwards:

$162.8912766 + 41.98988466(Y - 2016) + 346.8252071 + 12.29727575(Y - 2016)$; Y- Year

The first half of the equation represents the time trend of the trade balance for China from the rest of the world (excluding US) and the second half of the equation represents the trade balance between US and China.

Billions of US Dollars	Player 2 (China)		
Player 1 (United States)		No Tariffs	Tariffs
	No Tariffs	$(-134.3427929 + 15.95094241 \times (2018 - 2016) - 346.8252071 - 12.29727575 \times$	$(-134.3427929 + 15.95094241 \times (2018 - 2016) + (-346.8252071 - 12.29727575 \times (2018 -$

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

		$(2018-2016))\times(6/12)$, $(162.8912766+41.98988466\times(2018-2016)+346.8252071+12.29727575\times(2018-2016))\times(6/12)$	$2016))\times 1.08)\times(6/12)$, $(162.8912766+41.98988466\times(2018-2016)+(346.8252071+12.29727575\times(2018-2016))\times 1.08)\times(6/12)$
	Tariffs	$(-134.3427929+15.95094241\times(2018-2016)+(-346.8252071-12.29727575\times(2018-2016))/1.031)\times(6/12)$, $(162.8912766+41.98988466\times(2018-2016)+(346.8252071+12.29727575\times(2018-2016))/1.031)\times(6/12)$	$(-134.3427929+15.95094241\times(2018-2016)+(-346.8252071-12.29727575\times(2018-2016))\times 1.049)\times(6/12)$, $(162.8912766+41.98988466\times(2018-2016)+(346.8252071+12.29727575\times(2018-2016))\times 1.049)\times(6/12)$

Appendix G: Derivation of Payoffs for The Simultaneous Game of Trade War for Stage 2

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

Billions of US Dollars	Player 2 (China)		
Player 1 (United States)		No Tariffs	Tariffs
	No Tariffs	$(-134.3427929 + 15.95094241 * (2018 - 2016) - 346.8252071 - 12.29727575 * (2018 - 2016)) * (3/12)$, $(162.8912766 + 41.98988466 * (2018 - 2016) + 346.8252071 + 12.29727575 * (2018 - 2016)) * (3/12)$	$(-134.3427929 + 15.95094241 * (2018 - 2016) + (-346.8252071 - 12.29727575 * (2018 - 2016)) * 1.072) * (3/12)$, $(162.8912766 + 41.98988466 * (2018 - 2016) + (346.8252071 + 12.29727575 * (2018 - 2016)) * 1.072) * (3/12)$
	Tariffs	$(-134.3427929 + 15.95094241 * (2018 - 2016) + (-346.8252071 - 12.29727575 * (2018 - 2016))/1.038) * (3/12)$,	$(-134.3427929 + 15.95094241 * (2018 - 2016) + (-346.8252071 - 12.29727575 * (2018 - 2016)) * 1.034) * (3/12)$,

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

		$(162.8912766 + 41.98988466 * (2018 - 2016) + (346.8252071 + 12.29727575 * (2018 - 2016))/1.038) * (3/12)$	$(162.8912766 + 41.98988466 * (2018 - 2016) + (346.8252071 + 12.29727575 * (2018 - 2016)) * 1.034) * (3/12)$

Appendix H: Derivation of Payoffs for The Simultaneous Game of Trade War for Stage 3

Billions of US Dollars	Player 2 (China)		
Player 1 (United States)		No Tariffs	Tariffs
	No Tariffs	$(-134.3427929 + 15.95094241 * (2018 - 2016) - 346.8252071 - 12.29727575 * (2018 - 2016)) * (3/12) + (-134.3427929 + 15.95094241 * (2019 - 2016) - 346.8252071 - 12.29727575 * (2019 - 2016)) * (5/12);$	$(-134.3427929 + 15.95094241 * (2018 - 2016) + (-346.8252071 - 12.29727575 * (2018 - 2016)) * 1.183) * (3/12) + (-134.3427929 + 15.95094241 * (2019 - 2016) + (-346.8252071 - 12.29727575 * (2019 - 2016)) * 1.183) * (5/12);$

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

		$(162.8912766 + 41.98988466 * (2018 - 2016) + 346.8252071 + 12.29727575 * (2018 - 2016)) * (3/12) + (162.8912766 + 41.98988466 * (2019 - 2016) + 346.8252071 + 12.29727575 * (2019 - 2016)) * (5/12)$	$(162.8912766 + 41.98988466 * (2018 - 2016) + (346.8252071 + 12.29727575 * (2018 - 2016)) * 1.183) * (3/12) + (162.8912766 + 41.98988466 * (2019 - 2016) + (346.8252071 + 12.29727575 * (2019 - 2016)) * 1.183) * (5/12)$
	Tariffs	$(-134.3427929 + 15.95094241 * (2018 - 2016) + (-346.8252071 - 12.29727575 * (2018 - 2016))/1.12) * (3/12) + (-134.3427929 + 15.95094241 * (2019 - 2016) + (-346.8252071 - 12.29727575 * (2019 - 2016))/1.12) * (5/12);$	$= (-134.3427929 + 15.95094241 * (2018 - 2016) + (-346.8252071 - 12.29727575 * (2018 - 2016)) * 1.063) * (3/12) + (-134.3427929 + 15.95094241 * (2019 - 2016) + (-346.8252071 - 12.29727575 * (2019 - 2016)) * 1.063) * (5/12);$

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

		$(162.8912766 + 41.98988466 * (2018 - 2016) + (346.8252071 + 12.29727575 * (2018 - 2016))/1.12) * (3/12) + (162.8912766 + 41.98988466 * (2019 - 2016) + (346.8252071 + 12.29727575 * (2019 - 2016))/1.12) * (5/12)$	$(162.8912766 + 41.98988466 * (2018 - 2016) + (346.8252071 + 12.29727575 * (2018 - 2016)) * 1.063) * (3/12) + (162.8912766 + 41.98988466 * (2019 - 2016) + (346.8252071 + 12.29727575 * (2019 - 2016)) * 1.063) * (5/12)$

Appendix I: Derivation of Payoffs for The Simultaneous Game of Trade War for Stage 4

Billions of US Dollars	Player 2 (China)		
Player 1 (United States)		No Tariffs	Tariffs
	No Tariffs	$(-134.3427929 + 15.95094241 * (2019 - 2016) - 346.8252071 - 12.29727575 * (2019 - 2016)) * (3/12);$	$(-134.3427929 + 15.95094241 * (2019 - 2016) + (-346.8252071 - 12.29727575 * (2019 - 2016)) * 1.165) * (3/12);$

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

		$(162.8912766 + 41.98988466 * (2019 - 2016) + 346.8252071 + 12.29727575 * (2019 - 2016)) * (3/12)$	$(162.8912766 + 41.98988466 * (2019 - 2016) + (346.8252071 + 12.29727575 * (2019 - 2016)) * 1.165) * (3/12)$
	Tariffs	$(-134.3427929 + 15.95094241 * (2019 - 2016) + (-346.8252071 - 12.29727575 * (2019 - 2016))/1.12) * (3/12);$ $(162.8912766 + 41.98988466 * (2019 - 2016) + (346.8252071 + 12.29727575 * (2019 - 2016))/1.12) * (3/12)$	$(-134.3427929 + 15.95094241 * (2019 - 2016) + (-346.8252071 - 12.29727575 * (2019 - 2016)) * 1.045) * (3/12);$ $(162.8912766 + 41.98988466 * (2019 - 2016) + (346.8252071 + 12.29727575 * (2019 - 2016)) * 1.045) * (3/12)$

Appendix J: Derivation of Payoffs for The Simultaneous Game of Trade War for Stage 5

Billions of US Dollars	Player 2 (China)		
Player 1 (United States)		No Tariffs	Tariffs
	No Tariffs	$(-134.3427929 + 15.95094241 * (2019 -$	$(-134.3427929 + 15.95094241 * (2019 -$

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

		2016) − 346.8252071 − 12.29727575 ∗ (2019 − 2016)) ∗ (4/12) + (−134.3427929 + 15.95094241 ∗ (2020 − 2016) − 346.8252071 − 12.29727575 ∗ (2020 − 2016)) ∗ (1/ 12);(162.8912766 + 41.98988466 ∗ (2019 − 2016) + 346.8252071 + 12.29727575 ∗ (2019 − 2016)) ∗ (4/12) + (162.8912766 + 41.98988466 ∗ (2020 − 2016) + 346.8252071 + 12.29727575 ∗ (2020 − 2016)) ∗ (1/12)	2016) + (−346.8252071 − 12.29727575 ∗ (2019 − 2016)) ∗ 1.211) ∗ (4/12) + (−134.3427929 + 15.95094241 ∗ (2020 − 2016) + (−346.8252071 − 12.29727575 ∗ (2020 − 2016)) ∗ 1.211) ∗ (1/12);(162.8912766 + 41.98988466 ∗ (2019 − 2016) + (346.8252071 + 12.29727575 ∗ (2019 − 2016)) ∗ 1.183) ∗ (4/12) + (162.8912766 + 41.98988466 ∗ (2020 − 2016) + (346.8252071 + 12.29727575 ∗ (2020 − 2016)) ∗ 1.183) ∗ (1/12)
	Tariffs	(−134.3427929 + 15.95094241 ∗ (2019 − 2016) + (−346.8252071 − 12.29727575 ∗ (2019 − 2016))/1.21) ∗	(−134.3427929 + 15.95094241 ∗ (2019 − 2016) + (−346.8252071 − 12.29727575 ∗ (2019 − 2016)) ∗ 1.001) ∗

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

		$(4/12) + (-134.3427929 + 15.95094241 * (2020 - 2016) + (-346.8252071 - 12.29727575 * (2020 - 2016))/1.21) * (1/12); (162.8912766 + 41.98988466 * (2019 - 2016) + (346.8252071 + 12.29727575 * (2019 - 2016))/1.21) * (4/12) + (162.8912766 + 41.98988466 * (2020 - 2016) + (346.8252071 + 12.29727575 * (2020 - 2016))/1.21) * (1/12)$	$(4/12) + (-134.3427929 + 15.95094241 * (2020 - 2016) + (-346.8252071 - 12.29727575 * (2020 - 2016)) * 1.001) * (1/12); (162.8912766 + 41.98988466 * (2019 - 2016) + (346.8252071 + 12.29727575 * (2019 - 2016)) * 1.001) * (4/12) + (162.8912766 + 41.98988466 * (2020 - 2016) + (346.8252071 + 12.29727575 * (2020 - 2016)) * 1.001) * (1/12)$

Appendix K: Derivation of Payoffs for Representation of Game Through Trade Volume for Stage 1

Similar to the previous section's payoffs and equations, the equations and returns are derived by considering trade volume, rather than trade balance.

Equations for the trade balance of both nations have been calculated by using historical data from 2010 to 2016, while adding a time trend as well. This assumes that the trend of trade balance for both nations seen from 2010 to 2016 will carry forward in future years as well.

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

Equation for Exports of US in a Free-Trade Era from 2017 onwards:

$2122.329216 + 56.98688274(Y - 2016) + 115.5947845 + 3.947283922(Y - 2016)$; Y-Year

The first half of the equation represents the time trend of the exports for US from the rest of the world (excluding China) and the second half of the equation represents the exports from China.

Equation for Exports of China in a Free-Trade Era from 2017 onwards:

$1635.21718 + 70.32946887(Y - 2016) + 462.4199916 + 16.24455967(Y - 2016)$; Y-Year

The first half of the equation represents the time trend of the exports for China from the rest of the world (excluding US) and the second half of the equation represents the exports from US.

Equation for Imports of US in a Free-Trade Era from 2017 onwards:

$2256.672008 + 41.03594033(Y - 2016) + 462.4199916 + 16.24455967(Y - 2016)$; Y-Year

The first half of the equation represents the time trend of the imports for US from the rest of the world (excluding China) and the second half of the equation represents the imports from China.

Equation for Imports of China in a Free-Trade Era from 2017 onwards:

$1472.325904 + 28.33958421(Y - 2016) + 115.5947845 + 3.947283922(Y - 2016)$; Y-Year

The first half of the equation represents the time trend of the imports for China from the rest of the world (excluding US) and the second half of the equation represents the imports from US.

Billions of US Dollars	Player 2 (China)		
Player 1 (United States)		No Tariffs	Tariffs
	No Tariffs	$(2122.329216 + 56.98688274 * (2018 - 2016) + 115.5947845 + 3.947283922 * (2018 - 2016) + 2256.672008 +$	$((2122.329216 + 56.98688274 * (2018 - 2016) + 115.5947845 + 3.947283922 * (2018 - 2016))/1.08 +$

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

		$41.03594033 * (2018 - 2016) + 462.4199916 + 16.24455967 * (2018 - 2016)) * (6/12);$ $(1635.21718 + 70.32946887 * (2018 - 2016) + 462.4199916 + 16.24455967 * (2018 - 2016) + 1472.325904 + 28.33958421 * (2018 - 2016) + 115.5947845 + 3.947283922 * (2018 - 2016)) * (6/12)$	$2256.672008 + 41.03594033 * (2018 - 2016) + 462.4199916 + 16.24455967 * (2018 - 2016)) * (6/12);$ $(1635.21718 + 70.32946887 * (2018 - 2016) + 462.4199916 + 16.24455967 * (2018 - 2016) + (1472.325904 + 28.33958421 * (2018 - 2016) + 115.5947845 + 3.947283922 * (2018 - 2016))/1.08) * (6/12)$
	Tariffs	$(2122.329216 + 56.98688274 * (2018 - 2016) + 115.5947845 + 3.947283922 * (2018 - 2016) + (2256.672008 + 41.03594033 * (2018 - 2016) + 462.4199916 + 16.24455967 * (2018 - 2016))/1.031) * (6/12);$ $((1635.21718 + 70.32946887 * (2018 - 2016) + 462.4199916 +$	$((2122.329216 + 56.98688274 * (2018 - 2016) + 115.5947845 + 3.947283922 * (2018 - 2016))/1.08 + (2256.672008 + 41.03594033 * (2018 - 2016) + 462.4199916 + 16.24455967 * (2018 - 2016))/1.031) * (6/12);$ $((1635.21718 + 70.32946887 * (2018 - 2016) + 462.4199916 +$

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

		$16.24455967 * (2018 - 2016))/1.031 + 1472.325904 + 28.33958421 * (2018 - 2016) + 115.5947845 + 3.947283922 * (2018 - 2016)) * (6/12)$	$16.24455967 * (2018 - 2016))/1.031 + (1472.325904 + 28.33958421 * (2018 - 2016) + 115.5947845 + 3.947283922 * (2018 - 2016))/1.08) * (6/12)$

Appendix L: Derivation of Payoffs for Representation of Game Through Trade Volume for Stage 2

Billions of US Dollars	Player 2 (China)		
Player 1 (United States)		No Tariffs	Tariffs
	No Tariffs	$(2122.329216 + 56.98688274 * (2018 - 2016) + 115.5947845 + 3.947283922 * (2018 - 2016) + 2256.672008 + 41.03594033 * (2018 - 2016) + 462.4199916 + 16.24455967 * (2018 - 2016)) * (3/12);$	$((2122.329216 + 56.98688274 * (2018 - 2016) + 115.5947845 + 3.947283922 * (2018 - 2016))/1.072 + 2256.672008 + 41.03594033 * (2018 - 2016) + 462.4199916 + 16.24455967 * (2018 - 2016)) * (3/12);$

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

		(1635.21718 + 70.32946887 ∗ (2018 − 2016) + 462.4199916 + 16.24455967 ∗ (2018 − 2016) + 1472.325904 + 28.33958421 ∗ (2018 − 2016) + 115.5947845 + 3.947283922 ∗ (2018 − 2016)) ∗ (3/12)	(1635.21718 + 70.32946887 ∗ (2018 − 2016) + 462.4199916 + 16.24455967 ∗ (2018 − 2016) + (1472.325904 + 28.33958421 ∗ (2018 − 2016) + 115.5947845 + 3.947283922 ∗ (2018 − 2016))/1.072) ∗ (3/12)
	Tariffs	(2122.329216 + 56.98688274 ∗ (2018 − 2016) + 115.5947845 + 3.947283922 ∗ (2018 − 2016) + (2256.672008 + 41.03594033 ∗ (2018 − 2016) + 462.4199916 + 16.24455967 ∗ (2018 − 2016))/1.038) ∗ (3/12); ((1635.21718 + 70.32946887 ∗ (2018 − 2016) + 462.4199916 + 16.24455967 ∗ (2018 − 2016))/1.038 + 1472.325904 + 28.33958421 ∗ (2018 − 2016) + 115.5947845 + 3.947283922 ∗ (2018 −	((2122.329216 + 56.98688274 ∗ (2018 − 2016) + 115.5947845 + 3.947283922 ∗ (2018 − 2016))/1.072 + (2256.672008 + 41.03594033 ∗ (2018 − 2016) + 462.4199916 + 16.24455967 ∗ (2018 − 2016))/1.038) ∗ (3/12); ((1635.21718 + 70.32946887 ∗ (2018 − 2016) + 462.4199916 + 16.24455967 ∗ (2018 − 2016))/1.038 + (1472.325904 + 28.33958421 ∗ (2018 − 2016) + 115.5947845 + 3.947283922 ∗ (2018 −

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

		$2016)) * (3/12)$	$2016))/1.072) * (3/12)$

Appendix M: Derivation of Payoffs for Representation of Game Through Trade Volume for Stage 3

Billions of US Dollars	Player 2 (China)		
Player 1 (United States)		No Tariffs	Tariffs
	No Tariffs	$(2122.329216 + 56.98688274 * (2018 - 2016) + 115.5947845 + 3.947283922 * (2018 - 2016) + 2256.672008 + 41.03594033 * (2018 - 2016) + 462.4199916 + 16.24455967 * (2018 - 2016)) * (3/12) + (2122.329216 + 56.98688274 * (2019 - 2016) + 115.5947845 + 3.947283922 * (2019 - 2016) + 2256.672008 + 41.03594033 * (2019 - 2016) + 462.4199916 + 16.24455967 * (2019 - 2016)) * (5/12);$ $(1635.21718 + 70.32946887 * (2018 -$	$((2122.329216 + 56.98688274 * (2018 - 2016) + 115.5947845 + 3.947283922 * (2018 - 2016))/1.183 + 2256.672008 + 41.03594033 * (2018 - 2016) + 462.4199916 + 16.24455967 * (2018 - 2016)) * (3/12) + ((2122.329216 + 56.98688274 * (2019 - 2016) + 115.5947845 + 3.947283922 * (2019 - 2016))/1.183 + 2256.672008 + 41.03594033 * (2019 - 2016) + 462.4199916 + 16.24455967 * (2019 - 2016)) * (5/12);$

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

		2016) + 462.4199916 + 16.24455967 ∗ (2018 − 2016) + 1472.325904 + 28.33958421 ∗ (2018 − 2016) + 115.5947845 + 3.947283922 ∗ (2018 − 2016)) ∗ (3/12) + (1635.21718 + 70.32946887 ∗ (2019 − 2016) + 462.4199916 + 16.24455967 ∗ (2019 − 2016) + 1472.325904 + 28.33958421 ∗ (2019 − 2016) + 115.5947845 + 3.947283922 ∗ (2019 − 2016)) ∗ (5/12)	(1635.21718 + 70.32946887 ∗ (2018 − 2016) + 462.4199916 + 16.24455967 ∗ (2018 − 2016) + (1472.325904 + 28.33958421 ∗ (2018 − 2016) + 115.5947845 + 3.947283922 ∗ (2018 − 2016))/1.183) ∗ (3/12) + (1635.21718 + 70.32946887 ∗ (2019 − 2016) + 462.4199916 + 16.24455967 ∗ (2019 − 2016) + (1472.325904 + 28.33958421 ∗ (2019 − 2016) + 115.5947845 + 3.947283922 ∗ (2019 − 2016))/1.183) ∗ (5/12)
	Tariffs	(2122.329216 + 56.98688274 ∗ (2018 − 2016) + 115.5947845 + 3.947283922 ∗ (2018 − 2016) + (2256.672008 + 41.03594033 ∗ (2018 − 2016) + 462.4199916 + 16.24455967 ∗ (2018 − 2016))/1.12) ∗ (3/12) + (2122.329216 +	((2122.329216 + 56.98688274 ∗ (2018 − 2016) + 115.5947845 + 3.947283922 ∗ (2018 − 2016))/1.183 + (2256.672008 + 41.03594033 ∗ (2018 − 2016) + 462.4199916 + 16.24455967 ∗ (2018 − 2016))/1.12) ∗ (3/12) +

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

		56.98688274 ∗ (2019 − 2016) + 115.5947845 + 3.947283922 ∗ (2019 − 2016) + (2256.672008 + 41.03594033 ∗ (2019 − 2016) + 462.4199916 + 16.24455967 ∗ (2019 − 2016))/1.12) ∗ (5/12);((1635.21718 + 70.32946887 ∗ (2018 − 2016) + 462.4199916 + 16.24455967 ∗ (2018 − 2016))/1.12 + 1472.325904 + 28.33958421 ∗ (2018 − 2016) + 115.5947845 + 3.947283922 ∗ (2018 − 2016)) ∗ (3/12) + ((1635.21718 + 70.32946887 ∗ (2019 − 2016) + 462.4199916 + 16.24455967 ∗ (2019 − 2016))/1.12 + 1472.325904 + 28.33958421 ∗ (2019 − 2016) + 115.5947845 + 3.947283922 ∗ (2019 − 2016)) ∗ (5/12)	((2122.329216 + 56.98688274 ∗ (2019 − 2016) + 115.5947845 + 3.947283922 ∗ (2019 − 2016))/1.183 + (2256.672008 + 41.03594033 ∗ (2019 − 2016) + 462.4199916 + 16.24455967 ∗ (2019 − 2016))/1.12) ∗ (5/12); ((1635.21718 + 70.32946887 ∗ (2018 − 2016) + 462.4199916 + 16.24455967 ∗ (2018 − 2016))/1.12 + (1472.325904 + 28.33958421 ∗ (2018 − 2016) + 115.5947845 + 3.947283922 ∗ (2018 − 2016))/1.183) ∗ (3/12) + ((1635.21718 + 70.32946887 ∗ (2019 − 2016) + 462.4199916 + 16.24455967 ∗ (2019 − 2016))/1.12 + (1472.325904 + 28.33958421 ∗ (2019 − 2016) + 115.5947845 +

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

			$3.947283922 * (2019 - 2016))/1.183) * (5/12)$

Appendix N: Derivation of Payoffs for Representation of Game Through Trade Volume for Stage 4

Billions of US Dollars	Player 2 (China)		
Player 1 (United States)		No Tariffs	Tariffs
	No Tariffs	$(2122.329216 + 56.98688274 * (2019 - 2016) + 115.5947845 + 3.947283922 * (2019 - 2016) + 2256.672008 + 41.03594033 * (2019 - 2016) + 462.4199916 + 16.24455967 * (2019 - 2016)) * (3/12);$ $(1635.21718 + 70.32946887 * (2019 - 2016) + 462.4199916 + 16.24455967 * (2019 - 2016) + 1472.325904 + 28.33958421 * (2019 - 2016) + 115.5947845 + 3.947283922 * (2019 - 2016)) * (3/12)$	$((2122.329216 + 56.98688274 * (2019 - 2016) + 115.5947845 + 3.947283922 * (2019 - 2016))/1.165 + 2256.672008 + 41.03594033 * (2019 - 2016) + 462.4199916 + 16.24455967 * (2019 - 2016)) * (3/12);$ $(1635.21718 + 70.32946887 * (2019 - 2016) + 462.4199916 + 16.24455967 * (2019 - 2016) + (1472.325904 + 28.33958421 * (2019 - 2016) + 115.5947845 + 3.947283922 * (2019 - 2016))/1.165) * (3/12)$

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

	Tariffs	$(2122.329216 + 56.98688274 * (2019 - 2016) + 115.5947845 + 3.947283922 * (2019 - 2016) + (2256.672008 + 41.03594033 * (2019 - 2016) + 462.4199916 + 16.24455967 * (2019 - 2016))/1.12) * (3/12); ((1635.21718 + 70.32946887 * (2019 - 2016) + 462.4199916 + 16.24455967 * (2019 - 2016))/1.12 + 1472.325904 + 28.33958421 * (2019 - 2016) + 115.5947845 + 3.947283922 * (2019 - 2016)) * (3/12)$	$((2122.329216 + 56.98688274 * (2019 - 2016) + 115.5947845 + 3.947283922 * (2019 - 2016))/1.165 + (2256.672008 + 41.03594033 * (2019 - 2016) + 462.4199916 + 16.24455967 * (2019 - 2016))/1.12) * (3/12); ((1635.21718 + 70.32946887 * (2019 - 2016) + 462.4199916 + 16.24455967 * (2019 - 2016))/1.12 + (1472.325904 + 28.33958421 * (2019 - 2016) + 115.5947845 + 3.947283922 * (2019 - 2016))/1.165) * (3/12)$

Appendix O: Derivation of Payoffs for Representation of Game Through Trade Volume for Stage 5

Billions of US Dollars	Player 2 (China)		
Player 1 (United		No Tariffs	Tariffs
	No Tariffs	(2122.329216 +	((2122.329216 +

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

States)		$56.98688274 * (2019 - 2016) + 115.5947845 + 3.947283922 * (2019 - 2016) + 2256.672008 + 41.03594033 * (2019 - 2016) + 462.4199916 + 16.24455967 * (2019 - 2016)) * (4/12) + (2122.329216 + 56.98688274 * (2020 - 2016) + 115.5947845 + 3.947283922 * (2020 - 2016) + 2256.672008 + 41.03594033 * (2020 - 2016) + 462.4199916 + 16.24455967 * (2020 - 2016)) * (1/12); (1635.21718 + 70.32946887 * (2019 - 2016) + 462.4199916 + 16.24455967 * (2019 - 2016) + 1472.325904 + 28.33958421 * (2019 - 2016) + 115.5947845 + 3.947283922 * (2019 - 2016)) * (4/12) + (1635.21718 + 70.32946887 * (2020 -$	$56.98688274 * (2019 - 2016) + 115.5947845 + 3.947283922 * (2019 - 2016))/1.211 + 2256.672008 + 41.03594033 * (2019 - 2016) + 462.4199916 + 16.24455967 * (2019 - 2016)) * (4/12) + ((2122.329216 + 56.98688274 * (2020 - 2016) + 115.5947845 + 3.947283922 * (2020 - 2016))/1.211 + 2256.672008 + 41.03594033 * (2020 - 2016) + 462.4199916 + 16.24455967 * (2020 - 2016)) * (1/12); (1635.21718 + 70.32946887 * (2019 - 2016) + 462.4199916 + 16.24455967 * (2019 - 2016) + (1472.325904 + 28.33958421 * (2019 - 2016) + 115.5947845 + 3.947283922 * (2019 - 2016))/1.211) * (4/12) +$

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

		2016) + 462.4199916 + 16.24455967 ∗ (2020 − 2016) + 1472.325904 + 28.33958421 ∗ (2020 − 2016) + 115.5947845 + 3.947283922 ∗ (2020 − 2016)) ∗ (1/12)	(1635.21718 + 70.32946887 ∗ (2020 − 2016) + 462.4199916 + 16.24455967 ∗ (2020 − 2016) + (1472.325904 + 28.33958421 ∗ (2020 − 2016) + 115.5947845 + 3.947283922 ∗ (2020 − 2016))/1.211) ∗ (1/12)
	Tariffs	(2122.329216 + 56.98688274 ∗ (2019 − 2016) + 115.5947845 + 3.947283922 ∗ (2019 − 2016) + (2256.672008 + 41.03594033 ∗ (2019 − 2016) + 462.4199916 + 16.24455967 ∗ (2019 − 2016))/1.21) ∗ (4/12) + (2122.329216 + 56.98688274 ∗ (2020 − 2016) + 115.5947845 + 3.947283922 ∗ (2020 − 2016) + (2256.672008 + 41.03594033 ∗ (2020 − 2016) + 462.4199916 + 16.24455967 ∗ (2020 − 2016))/1.21) ∗ (1/12); ((1635.21718 +	((2122.329216 + 56.98688274 ∗ (2019 − 2016) + 115.5947845 + 3.947283922 ∗ (2019 − 2016))/1.211 + (2256.672008 + 41.03594033 ∗ (2019 − 2016) + 462.4199916 + 16.24455967 ∗ (2019 − 2016))/1.21) ∗ (4/12) + ((2122.329216 + 56.98688274 ∗ (2020 − 2016) + 115.5947845 + 3.947283922 ∗ (2020 − 2016))/1.211 + (2256.672008 + 41.03594033 ∗ (2020 − 2016) + 462.4199916 + 16.24455967 ∗ (2020 −

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

		$70.32946887 * (2019 - 2016) + 462.4199916 + 16.24455967 * (2019 - 2016))/1.21 + 1472.325904 + 28.33958421 * (2019 - 2016) + 115.5947845 + 3.947283922 * (2019 - 2016)) * (4/12) + ((1635.21718 + 70.32946887 * (2020 - 2016) + 462.4199916 + 16.24455967 * (2020 - 2016))/1.21 + 1472.325904 + 28.33958421 * (2020 - 2016) + 115.5947845 + 3.947283922 * (2020 - 2016)) * (1/12)$	$2016))/1.21) * (1/12); ((1635.21718 + 70.32946887 * (2019 - 2016) + 462.4199916 + 16.24455967 * (2019 - 2016))/1.21 + (1472.325904 + 28.33958421 * (2019 - 2016) + 115.5947845 + 3.947283922 * (2019 - 2016))/1.211) * (4/12) + ((1635.21718 + 70.32946887 * (2020 - 2016) + 462.4199916 + 16.24455967 * (2020 - 2016))/1.21 + (1472.325904 + 28.33958421 * (2020 - 2016) + 115.5947845 + 3.947283922 * (2020 - 2016))/1.211) * (1/12)$

Appendix P: Derivation of Trade Diversion Constants for Stage 1

Billions of US Dollars Per Month	Player 2 (China)		
Player 1 (United States)		No Tariffs	Tariffs
	No Tariffs	2596.722667,	2509.322951,

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

		1961.639827	1900.43633+C
	Tariffs	2554.121676+US, 1927.500961	2466.72196+US, 1866.297463+C

From the above payoff table, the following conditions are derived, in order to match expectations with reality:

$1961.639827 < 1900.43633 + C;$

$2509.322951 < 2466.72196 + US;$

$2596.722667 < 2554.121676 + US;$

$1927.500961 < 1866.297463 + C;$

$2596.722667 > 2466.72196 + US;$

$1961.639827 > 1866.297463 + C$

The first four equations are needed to ensure that implementing tariffs is the dominant strategy for both nations. Meanwhile, the last two equations are necessary solely to maintain the game as Prisoner's Dilemma, i.e. to attain a sub-optimal equilibrium. One can notice that the value of the constants would be the difference between the payoffs from the strategies available to the player given that the other player is assumed to have picked a strategy. This difference is the same irrespective of what the strategy chosen by the other player, meaning that only two equations are needed to satisfy the condition of making implementing tariffs as the dominant strategy. Through simplification of above equations, the following condition is derived:

$61.20349721 < C < 130.0007068$

$42.60099078 < US < 95.34236341$

If the above conditions for the value of the respective constants are met, then the game represents Prisoner's Dilemma, and would insinuate a loser-all situation if both decide to break away from their cooperation, i.e. free trade, and cheat, i.e. implement tariffs. As mentioned before, the value of constant represents the trade diversion that each country would encounter if they implement tariffs. This means that whatever trade volume that would be decreased between United States and China, due to tariffs, would be offset partially by increasing their trade interactions with

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

other countries. Nicita (2019) proved that the overall trade volume would be negative, which would imply that if trade volume is aimed to be maximized by both nations, then by implementing tariffs, trade volume will not increase even if trade reduction between US and China is offset by other sources. This implies that the reduction in trade volume must be greater than the increase in trade volume from other nations.

Appendix Q: Derivation of Trade Diversion Constants for Stage 2

Billions of US Dollars Per Month	Player 2 (China)		
Player 1 (United States)		No Tariffs	Tariffs
	No Tariffs	1298.361333, 980.8199134	1258.737955, 953.0728055+C
	Tariffs	1272.42713+US, 960.0371969	1232.803751+US, 932.290089+C

Conditions for Prisoner's Dilemma:

$960.0371969 < 932.290089 + C;$

$1258.737955 < 1232.803751 + US;$

$1298.361333 > 1232.803751 + US;$

$980.8199134 > 932.290089 + C$

Inequality Conditions to Attain a Prisoner's Dilemma for Stage 2:

$25.93420375 < US < 65.55758249$

$27.74710788 < C < 48.52982433$

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

Appendix R: Derivation of Trade Diversion Constants for Stage 3

Billions of US Dollars Per Month	Player 2 (China)		
Player 1 (United States)		No Tariffs	Tariffs
	No Tariffs	3511.553, 2665.045143	3264.265684, 2492.546247+C
	Tariffs	3306.592049+US, 2498.981286	3059.304733+US, 2326.48239+C

Conditions for Prisoner's Dilemma:

$2665.045143 < 2492.546247 + C$;

$3264.265684 < 3059.304733 + \text{US}$;

$3511.553 > 3059.304733 + US$;

$2665.045143 > 2326.48239 + \text{C}$

Inequality Conditions to Attain a Prisoner's Dilemma for Stage 3:

$204.9609509 < US < 452.248267$

$172.4988956 < C < 338.5627525$

Appendix S: Derivation of Trade Diversion Constants for Stage 4

Billions of US Dollars Per Month	Player 2 (China)		
Player 1 (United States)		No Tariffs	Tariffs
	No Tariffs	1327.915,	1242.202581,

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

		1010.535138	950.8808643+C
	Tariffs	1250.479281+US, 947.391586	1164.766862+US, 887.7373128+C

Conditions for Prisoner's Dilemma:

$947.391586 < 887.7373128 + C$;

$1242.202581 < 1164.766862 + US$;

$1327.915 > 1164.766862 + US$;

$1010.535138 > 887.7373128 + C$

Inequality Conditions to Attain a Prisoner's Dilemma for Stage 4:

$77.43571874 < US < 163.1481377$

$59.65427325 < C < 122.7978248$

Appendix T: Derivation of Trade Diversion Constants for Stage 5

Billions of US Dollars Per Month	Player 2 (China)		
Player 1 (United States)		No Tariffs	Tariffs
	No Tariffs	2223.042889, 1694.130304	2046.417265, 1571.349077+C
	Tariffs	2013.159343+US, 1522.408006	1836.53372+US, 1399.626779+C

Conditions for Prisoner's Dilemma:

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

$1522.408006 < 1399.626779 + C;$

$2046.417265 < 1836.53372 + US;$

$2223.042889 > 1836.53372 + US;$

$1694.130304 > 1399.626779 + \mathrm{C}$

Inequality Conditions to Attain a Prisoner's Dilemma for Stage 5:

$209.8835454 < US < 386.5091694$

$122.7812272 < C < 294.5035251$

Appendix U: Derivation of Payoffs (Mode is Trade Balance) for Repeated Games

$$Cooperation\ Payoffs\ (US): \sum_{n=1}^{5} Stage_n\ Payoffs\ for\ US\ (Both\ Cooperate)$$

$$= -236.9303333 - 118.4651667 - 314.38475 - 117.55175 - 195.6151111$$

$$= -982.9471111$$

$$Cooperation\ Payoffs\ (China): \sum_{n=1}^{5} Stage_n\ Payoffs\ for\ China\ (Both\ Cooperate)$$

$$= 309.1454023 + 154.5727011 + 434.8135199 + 168.1444912 + 284.7647488$$

$$= 1351.440863$$

$$Deflection\ (Stage\ 1) Payoffs\ (US): Stage\ 1\ Payoff\ (US\ Deflects\ and\ China\ Cooperates)$$
$$+ \sum_{n=2}^{5} Stage_n\ Payoffs\ for\ US\ (Both\ US\ and\ China\ Employ\ Tariffs)$$

$$= -231.3464281 - 121.6222346 - 330.3071834 - 121.8685666 - 195.776018$$

$$= -1000.920431$$

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

$$Deflection\ (Stage\ 1) Payoffs\ (China): Stage\ 1\ Payoff\ (China\ Deflects\ and\ US\ Cooperates) + \sum_{n=2}^{5} Stage_n\ Payoffs\ for\ China\ (Both\ US\ and\ China\ Employ\ Tariffs)$$

$$= 324.0021926 + 157.7297691 + 450.7359532 + 172.4613079 + 284.9256556$$

$$= 1389.854878$$

Appendix V: Derivation of Payoffs (Mode is Trade Volume) for Repeated Games

$$Cooperation\ Payoffs\ (US): \sum_{n=1}^{5} Stage_n\ Payoffs\ for\ US\ (Both\ Cooperate)$$

$$= 2596.722667 + 1298.361333 + 3511.553 + 1327.915 + 2223.042889$$

$$= 10957.59489$$

$$Cooperation\ Payoffs\ (China): \sum_{n=1}^{5} Stage_n\ Payoffs\ for\ China\ (Both\ Cooperate)$$

$$= 1961.639827 + 980.8199134 + 2665.045143 + 1010.535138 + 1694.130304$$

$$= 8312.170324$$

$$Deflection\ (Stage\ 1) Payoffs\ (US): Stage\ 1\ Payoff\ (US\ Deflects\ and\ China\ Cooperates) + \sum_{n=2}^{5} Stage_n\ Payoffs\ for\ US\ (Both\ US\ and\ China\ Employ\ Tariffs)$$

$$= 2597.121676 + 1258.803751 + 3264.304733 + 1242.766862 + 2046.53372$$

$$= 10409.53074$$

$$Deflection\ (Stage\ 1) Payoffs\ (China): Stage\ 1\ Payoff\ (China\ Deflects\ and\ US\ Cooperates) + \sum_{n=2}^{5} Stage_n\ Payoffs\ for\ China\ (Both\ US\ and\ China\ Employ\ Tariffs)$$

ISSN: 2455-8834

Volume:05, Issue:11 "November 2020"

$$= 1962.43633 + 960.290089 + 2499.48239 + 947.7373128 + 1522.626779$$

$$= 7892.5729$$

