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14. ABSTRACT

As China continues to gain economic influence rivaling that of the United States, does the United States have reason to be concerned? The United States has typically encouraged the prosperity of partner United Nations members, but are China's economic policies in line with the best interests of the United States? In an attempt to answer these questions, the author used game theory principles to design a model game outlining the interactions between the US and China. This model was based on a review of both US and Chinese foreign policy, with particular emphasis on China's Belt and Road Initiative and the US response. Rather than use only a single classic game to explain the interaction, the author merged the mechanics of multiple games to create a unique game, which included several rational decisions for each party. Possible choices included cooperation, competition, hostile escalation, and resignation. Two sub-games reduced the complexity of the game and accompanied the main game, and the researcher analyzed all three games to determine the best player strategies using Nash equilibriums. The results showed that the US - China game had a pure equilibrium point, providing a forecast for what decisions strategies would be prudent for each side.

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TITLE: Modeling Chinese Economic Expansion using Game Theory

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Executive Summary

Title: Modeling Chinese Economic Expansion using Game Theory

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Thesis: This research shows that game theory is a valid method for modeling the economic interactions between China and the United States. Using the game model created, economic planners will be able to use the forecasts provided by the game to determine economic strategies most beneficial for each party.

Discussion: As China continues to gain economic influence rivaling that of the United States, does the United States have reason to be concerned? The United States has typically encouraged the prosperity of partner United Nations members, but are China's economic policies in line with the best interests of the United States? In an attempt to answer these questions, the author used game theory principles to design a model game outlining the interactions between the US and China. This model was based on a review of both US and Chinese foreign policy, with particular emphasis on China's Belt and Road Initiative and the US response. Rather than use only a single classic game to explain the interaction, the author merged the mechanics of multiple games to create a unique game, which included several rational decisions for each party. Possible choices included cooperation, competition, hostile escalation, and resignation. Two sub-games reduced the complexity of the game and accompanied the main game, and the researcher analyzed all three games to determine the best player strategies using Nash equilibriums. The results showed that the US - China game had a pure equilibrium point, providing a forecast for what decisions strategies would be prudent for each side.

Conclusion: Assuming infrastructure development realizes at least some economic gain, it seems that China is executing a good strategy by competing for economic investments. However, the United States seems to be executing a sub-optimal strategy according to the analysis. The optimal strategy for each party is to engage in economic competition to the benefit of the developing countries. Instead, the United States has adopted a diplomatic policy of trying to increase awareness by warning developing countries of China's unfair lending practices. If these warnings go unheeded, the outcome is similar to that of the United States either ceding or relinquishing the investments to China. Meanwhile, China continues to steadily invest its excess GDP and manpower in developing countries, further integrating itself into the global world market. Assuming this analysis is correct, one can expect the result of the long-term economic interaction between China and the US to be characterized by competition over the favor of developing nations for infrastructure development, coupled with information campaigns and economic actions short of military engagement, which discourage developing nations from working with the opposing nation.

DISCLAIMER

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Preface

Since I was a child, I have always appreciated games and the structure their rules provide. Eventually obtaining a bachelor's degree in Computer Science, my enthusiasm for the simple structure of a well-designed system only grew along with my education. The ability to functionally decompose a problem into small parts, encode those parts using simple rules, and then reconstruct them to design an elegant solution I find fascinating. That fascination with rule-based systems led me to learn about game theory.

While at Command and Staff College, I was introduced to the concept of using game theory to evaluate decisions, and its utility in describing complex decision-making strategies. Simultaneously, I began to learn of China's economic actions in the global stage. The more I learned about each, the more I believed I could tackle the complex problem of understanding the reason for China's actions, and discovering appropriate responses by the US. This research is the result of that effort to do what I have always enjoyed: reduce a complex problem to its most basic parts, encode those parts, and then observe what manifests when the pieces are reconstructed.

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I can observe the game theory is applied very much in economics. Generally, it would be wise to get into the mathematics as much as seems reasonable because the economists who use more mathematics are somehow more respected than those who use less. That's the trend.

John Forbes Nash, Jr., Nobel Laureate in Economic Sciences, 2004

As China continues to gain economic influence rivaling that of the United States, does the United States have reason to be concerned? The United States has typically encouraged the prosperity of partner United Nations members, but are China's economic policies in line with the best interests of the United States? While these might seem like complex questions with at best biased answers, an application of game theory principles to this situation may provide insight. This research aims to create a framework using game theory to evaluate potential responses by the United States to Chinese economic actions. First, a review of Chinese economic policy will be conducted in an attempt to discern Chinese economic strategy; this section will also offer some discussions of United States foreign economic policy for the purpose of comparison. Next, a brief background of game theory principles will be provided. This will be followed by a proposed model of the interactions between China and the United States, treating each as a unitary, rational actor. Finally, an analysis of the proposed model will be conducted, which will identify equilibrium points with the greatest benefit for each party. This analysis will then be followed by a discussion of possible variations or improvements to the game for future research efforts. This research should show that game theory is a potentially valid method for modeling the economic interactions between China and the United States. Using the game model created, economic planners should be

able to use the forecasts provided by the game to determine economic strategies most beneficial for each party.

Discussion of Chinese Foreign Economic Policy

In the socialist market economy managed by the Communist Party of China, ensuring continued economic growth not only builds confidence in the communist party but also preserves order within the nation. In addition to a comprehensive reform package designed to encourage market-driven policies combined with one-party state rule, China engages in partnerships abroad to generate stability within its borders. If capital and workers cannot be effectively invested and employed at home, Chinese leaders move them abroad to developing countries. Some sources have compared China's foreign investment in this regard to that of the Marshall Plan as conducted by the United States after World War II. As is the historical precedent for all great powers attempting to spread their influence, like the Marshall Plan China is focusing on areas such as new technology, overseas security, military development, and foreign aid. China's most noteworthy foreign aid package, known as the Belt and Road Initiative (BRI), is predicted to be seven times larger than the Marshall Plan.[1]

Five years ago Chinese President Xi Jinping laid out the BRI as a way to return China to the prominence it enjoyed in ages past. This initiative includes some sixty countries in an interconnected web of trading corridors with China situated at the hub. Speaking at a Kazakhstan university in 2013, the Chinese President expressed a desire to create a new economic belt that would connect China to Europe via infrastructure investment in Central Asia. Two years later in 2015, the National Development and Reform Commission (NDRC) of the People's Republic of China (PRC) issued its first edition of China's official action plan

to make the BRI a reality.[2] Some skeptical reactions to this proposal include that the BRI preys on weaker developing nations to China's benefit, and that China's true intent is to replace the US as the largest global economy. Regardless of China's true intentions, one certainty is that the Communist Party of China (CPC) must provide economic prosperity for the people of China in order to ensure its continued credibility as a viable government institution. This is especially important considering the relatively recent fall of the Soviet Union's communist regime. The BRI can provide economic growth to the frontier regions in China such as Tibet and Inner Mongolia, and that growth could be the cement that holds the relatively young PRC together. In this light, the BRI can be considered a multinational extension of infrastructure development in China's own interior with a by-product of global economic influence. A completed BRI would allow China to export its excess production, and would also give China easy access to natural resources that can be imported to fuel additional production. The six land trade routes proposed by the BRI in particular would allow China to insulate itself from US sea influence, and also avoid direct competition with areas traditionally influenced by the US.[3] By adopting a policy of aggressive economic development such as the BRI via both land and maritime initiatives, and supporting the BRI through targeted financial investments, China aims to return itself to great-power status while avoiding a military response from potential rivals such as the US.

The six land-based Economic Corridors (EC) proposed in the BRI constitute "the belt" of the initiative, and one of the primary routes includes infrastructure development in Russia. The China-Mongolia-Russia EC stretches from Harbin north of Beijing, through the Mongolian capital of Ulaanbaatar, and terminates north of Moscow near Saint Petersburg. While Russia may have initially resisted China's BRI plans as conflicting with its own

initiative in the region, the Eurasian Economic Union (EEU), the prospect of a partnership that balances against western economic influence (namely from the United Sates) has grown more appealing for Russia in recent years. Over the past decade China has increased its trade with Central Asian countries from $1 billion to $45 billion, representing China's ability to fill gaps in the Central Asian market with its own products. Unfortunately for Russia, the popularity of China's BRI as compared with Russia's increasingly unpopular EEU has all but forced the state to seek a compromise that allows both economic policies to coexist. Russia has made plays to limit BRI by ensuring it is involved in all decisions on development of the corridors that run through its borders, yet leaving China to be ultimately accountable for its execution. However, even these concessions will allow China to build the economic corridor it desires through the Russian mainland.[4]

To the south of the China-Mongolia-Russia EC falls the New Eurasia Land Bridge EC, linking China to Europe through Kazakhstan. This corridor not only connects China's east coast near Taiwan with central Kazakhstan by railway, but it also continues through Moscow, Minsk, Berlin, and finally concludes in Amsterdam. By linking the coasts of the East China Sea and the North Sea via land based railways instead of sea routes, a typical 36-day sea voyage takes only sixteen days when using this land bridge instead. If any one of the BRI's ECs harken back to the Silk Road of ancient days, it is this corridor. With China's desire to produce manufactured goods, this EC is China's bid to bring resources into the country to satisfy its increasing demands for raw materials and the energy needed to process them. Kazakhstan specifically accounts for two thirds of all trade with China along this EC, the vast majority of which is Chinese imports of oil, natural gas, and minerals. Guided by China's

socialist market economy, these resources are processed into manufactured goods, which in turn become exports sold for profit to fuel China's growing Gross Domestic Product (GDP).[5]

Branching off of the New Eurasia Land Bridge EC in Kazakstan, the China-Central Asia-West Asia EC travels through Iran, Iraq, and Syria to Turkey. Compared to the energy resources available from other BRI corridors, the significant amount of oil available in the Middle East makes this corridor perhaps the most lucrative for China's energy demands. While this corridor could also bring economic stability to the region and link it to the global economy via China, there are several roadblocks that must be addressed. Terrorism and military operations are commonplace, and political unrest continues to add to the instability of the region. As a result, funding or financing infrastructure comes at great risk, since all wars of instability may damage or destroy improvements. Furthermore, entire population centers uproot and become refugees during wartime, disrupting the work force and the economy of the region. Until stable governments prevail, developing this corridor to make it comparable to other ECs already under development may incur too great a cost.[6]

Similar to the China-Central Asia-West Asia EC, branching off of the New Eurasia Land Bridge is perhaps the shortest and most straightforward corridor connecting China to the Arabian Sea through Pakistan. The China-Pakistan EC flows from western China through Islamabad and ends in Pakistan's most populous port city of Karachi. Thus far in China's attempts to fully implement the BRI, the lion's share of investments have been on this EC. The Chinese Ministry of Foreign Affairs assesses that at least $14 billion have been applied to infrastructure improvements in Pakistan that would lead to an operable and stable corridor. However, while regional security does not pose the same challenges as those of the China-Central Asia-West Asia EC, it is still a valid concern. Nevertheless, Pakistan remains an eager

and willing participant in the BRI. Even if the economic gain of the China-Pakistan EC is modest for China, it gains influence over a strategic partner to balance against neighboring India.[7]

Moving to the eastern most corridor, the China-Indochina Peninsula EC will be China's economic link to the member countries of the Association of Southeast Asian Nations (ASEAN). The corridor encompasses routes through Vietnam, Laos, Thailand, and finally terminates in the Malaysian city of Kuala Lumpur. In addition to these countries, China views both the Philippines and Indonesia as important partners in this EC. In 2017, President Xi met with the Presidents of both countries to discuss cooperation on the BRI in the ASEAN region. Overall, China's offer to help fund developments in Southeast Asia has been generally welcomed by other ASEAN countries who see it as an opportunity to improve their shortfalls in transportation infrastructure. However, they must balance this need for capital investment into infrastructure with the influence this will give China in ASEAN issues. For example, there are tensions surrounding border disputes in the South China Sea, and ASEAN countries must consider the implications to decisions on territorial sovereignty should they become too dependent on financial aid from China. Since ASEAN may represent China's most important ally if the BRI is to be successful, it should certainly take advantage of this position.[8]

The final corridor of the BRI is the Bangladesh-China-India-Myanmar EC, which links to the China-Indochina Peninsula EC through Myanmar. The corridor loops from Bangladesh through the Indian port of Kolkata, and then back through Bangladesh before rejoining with the China-Indochina Peninsula EC. Interestingly, the areas covered by this corridor are some of the least developed regions of each country involved, making the prospect of infrastructure investment from China a very attractive prospect. In addition, this route represents the shortest

trade route between India and China, the "Southern Silk Route" of the 12th century, with Bangladesh and Myanmar positioned to benefit from any BRI projects to rejuvenate the route. However, India may be skeptical of China's claims for the BRI to be a "win-win" scenario for all involved. Should India acquiesce, it will join the likes of Russia, Pakistan, and ASEAN in helping China realize its vision of an interconnected "belt" of land trading corridors that will reshape the global economy.[9]

The BRI includes not only a series of interconnected land corridors, but also includes a "road" of maritime routes that supplement the land-based routes. China has referred to this as the "21st Century Maritime Silk Road," and it includes not just ports on China's southern coast, but also ports throughout the South China Sea. In particular, prominent ASEAN countries such as Vietnam, Indonesia, Malaysia, and Singapore are all a part of China's aspiration to support its BRI via maritime trade routes. In fact, all ten ASEAN members would stand to benefit from the economic investment that the Maritime Silk Road could provide. Investors might consider most of the ASEAN countries developing, and such financial support from China to improve port facilities throughout the region would improve the economic outlook for the entire region. However, China's reef expansion activities in the South China Sea have eroded friendly relations with ASEAN states who feel at best China is overstepping its territorial rights and at worst is infringing on their sovereignty. Tensions in this area also constitute a possible intervention by the United States, considering its interest in freedom of navigation and the volume of shipping transiting through the area. China must make a dedicated effort to demonstrate its ethical intentions for the region if the Maritime Silk Road is to succeed.[10]

Along with maritime interests in the South China Sea and the Malacca Strait, China holds similar interests in the Bay of Bengal and Arabian Sea, which can connect its Maritime Silk Road to both the Red and Mediterranean Seas. Such a maritime "road" when combined with the six "belts" of the BRI would link China to Europe and Central Asia by both land and sea via multiple redundant nodes. By supporting improvements to ports in Pakistan and Sri Lanka, China's policies aim to secure its sea lines of communication throughout the Indian Ocean. Such a policy might seem innocuous at first, since China may simply be ensuring trade security. However, with the border tensions in the South China Sea, countries such as India and the US may fear such tensions will bleed over into the Indian Ocean as well. These concerns are validated by China's official policies regarding BRI expansion and the financial institutions created to support such infrastructure improvements.[11]

As previously mentioned, China's NDRC released its Action Plan for building both the Silk Road Economic Belt and the 21st Century Maritime Silk Road in 2015. The BRI vision included the principles on which the BRI was founded, Chinese priorities on cooperation with other nations, and the methods of Chinese cooperation to achieve its BRI goals. This policy not only laid the framework for the BRI but also established new financial institutions to help finance the proposed infrastructure improvements.[12] Likened to the United Nations Development Program as a plan that would create benefits for underdeveloped countries throughout the world, these financial institutions backed by Chinese government funds are what give the plan its clout.[13]

The primary institution created by the BRI Action Plan to assist participating countries is the Asian Infrastructure Investment Bank (AIIB). Backed by a socialist market economy, AIIB's lending power is linked directly to the wealth of China. Through the AIIB the Chinese

government can loan interested nations billions of dollars for infrastructure development. This places AIIB in a position to compete with other global nation lenders such as World Bank and the Asian Development Bank. As of 2017, over sixty of the world's nations are members of the Chinese-managed bank, including notable members such as France, Germany, Italy, and the United Kingdom. However, the AIIB is not the only financial institution contributing funds to BRI development goals.[14]

In addition to the AIIB, the BRI Action Plan also established the Silk Road Fund. Created initially with a seed of $40 billion from President Xi, and with funds being added routinely since its inception, the stated purpose of the fund is to invest in infrastructure development projects that are related to the BRI. The fund has already signed sixteen contracts with developing countries to assist in transportation infrastructure and excavation of natural resources. Not only does the Chinese-backed fund propose projects that it will financially support, but it also accepts proposals from potential developers seeking funds for their projects. If the project is a good investment into the BRI campaign, the fund may accept the proposal and invest. Along with the AIIB and the BRI Action Plan from the NDRC, the Silk Road Fund is one of several CPC institutions that aim to turn the BRI ideal into a reality.[15]

In the BRI, China has offered an extremely ambitious attempt to recreate the historical Silk Road from the age of antiquity. This lofty ideal calls for multinational cooperation, the development of robust transportation networks through developing countries, free trade along these corridors once established, and Chinese-backed financial support when warranted. If completed in full the BRI would include sixty-five nations and cover a third of the world's landmass, provide a potential for economic prosperity to all involved. However, it also gives China the opportunity to take advantage of its position at the hub of the BRI. It may use

government wealth to undercut markets and install Chinese products in their place, driving smaller market players out of business. It may also leverage investments in BRI infrastructure to garner more favorable terms on resource imports, or even pressure developing countries to accept unfair terms on financial assistance for infrastructure development.[16] Perhaps most concerning for the US is the perception that China is excluding it from the initiative, denying it the potential benefits shared by all other nations connected to the BRI. If that perception becomes a reality, China may return to great-power status through economic gains of the BRI. Furthermore, it would accomplish this while avoiding military conflict if it handles territorial disputes in littoral regions appropriately. If the BRI continues to gain support, the US must determine how to participate in this evolving economic system or risk China overtaking it as the largest global economy.[17]

Discussion of United States Foreign Economic Policy

Before a discussion of US economic policies specifically, it is beneficial to address the importance of economic influence and its implications when considering all the instruments of a nation's power including diplomatic, informational, military, and economic actions. It may seem apparent, but without a powerful economy to fuel a nation's military it could be subject to the military influence of a neighbor nation with a more powerful military. The historical accounts of Smith, Hamilton, and List on the nature of mercantilism and its benefits for military ambitions can serve as evidence for this now accepted truth.[18] However, in the age of globalization a large national economy can do much more than simply transfer wealth into military power. If the wealthy nation becomes heavily integrated into global trade with other world nations, those less wealthy nations can join in the prosperity of the larger nation through

trade. Unfortunately, in some cases the economy of those less established nations may become dependent upon maintaining good trade relations with the wealthy nation. When this occurs, the wealthy nation is able to influence the dependent nation's diplomatic, informational, and military decisions through the threat of economic sanctions. This level of "economic power" can only be achieved by the wealthiest and most globally integrated nations in the world. It could be argued that the US's Marshall Plan, which helped to rebuild the struggling nations of Europe following the second World War, established such a dependency in some cases and helped propel the US to economic prominence. Since that time, the US has become so wealthy and economically stable that many world nations accept it as reserve currency.[19] However, if the US is to retain that position it must contend with China's economic growth.

In a move that could be argued as counter to the United States' "Pivot to the Pacific," shortly after President Trump took office in 2017 the US withdrew from the Tans-Pacific Partnership. Later in 2017, the President released the National Security Strategy (NSS) of the United States of America. The NSS contains no specific plan to compete with China for foreign infrastructure development in response to the BRI. It instead primarily focuses on rebuking China for stealing intellectual property from US companies. To its credit, the NSS does advise that developing nations should avoid predatory lending practices, yet it does little to specifically offer such countries an alternative. Furthermore, America's general foreign investments similar to those financed by the World Bank (the western world's version of the AIIB) would be cut by forty-two percent according to the budget proposals for 2018. This shows a steady pivot away from the principles that made the United States a world super power under the Marshall Plan.[20]

Most concerning for the United States could be China's actions when dealing with a developing country unable to make timely payments on its BRI infrastructure loans. Sri Lanka had borrowed money from China for investments on a new deep-water port but was unable to keep up with payments. In response, China took ownership of the project in a threat to Sri Lanka's national sovereignty. However, economic responses like this are not limited to BRI investments. Political conflicts with the Philippines saw sanctions on banana imports in 2015, and tensions with South Korea prompted China to force the closure of a number of South Korean owned businesses in 2016. These actions by China continue to show a pattern of economic pressure coupled with economic expansion, and the United States may be the only nation left with enough economic clout to effectively respond in order to maintain a global economic balance. However, the economic dynamic between the US and China is also shifting to China's advantage. The United States represented thirty one percent of the global economy in 2000 to China's four percent. However, in 2018 China has closed that margin to a twenty-four to fifteen percent gap. While the global economy is far from a zero-sum game, it may not be long before a communist country controls the largest share of it.[21]

Background on Game Theory

Seeing China's plan for economic expansion, several questions emerge from the United States perspective. Can the United States effectively forecast China's future economic actions in an effort to gain an initiative? Can the United States compete with such a forecasted strategy, and if so should it even try to compete? If it cannot compete, can and should it cooperate? If economic competition and cooperation are both unviable, should the United States ever escalate beyond economics and use other instruments of national power to gain an

advantage? Perhaps most importantly, is it rational for the United States to simply ignore China's economic expansion as inconsequential to its own national security? Game theory principles can be used to help answer many if not all of these important questions.

Game theory has had a profound impact on decision theory, especially in the realm of military and economic decision making. It can be argued that the roots of game theory as known today were based on the work of Neumann and Morgenstern when they published *Theory of Games and Economic Behavior* in 1944. In doing so, they created a framework of how complex cooperation and competition can be not only codified, but also analyzed and used in decision strategy forecasting. An economic theory at its foundation, their work was widely reviewed with enthusiasm by economists as a sound method for applying mathematical principles to the complexities of human decision making. Later works by Nash and Schelling solidified the link between mathematics and economics, and these principles were successfully used to effectively model complex human interactions like the Cuban Missile Crisis.[22] Economists today apply game theory in fields such as microeconomic theory, macroeconomic policy, and international trade negotiation. This makes game theory a valid method for the intended purpose, to model the military and economic interactions between the United States and China.[23]

At its most fundamental level game theory attempts to model a collection of decision making strategies between actors making rational decisions in both competition and cooperation.[24] In a game theory model, the possible decisions of each player are outlined and potential payoff values determined based on the decisions of each player. By reviewing poor and good decisions on the part of each player, an analyzer can evaluate the situation using the model to determine both good and bad decision making strategies for each player. While

some games are trivial and the best decision making strategies are self-evident, others are very complex and involve many variables and possible payoffs. A game theory analysis can be used to systematically take a very complex decision making environment and determine the best decision making strategies.

A common method for displaying a game model is the "normal form," a two-by-two matrix showing all options available to players.[25] Along the side of the matrix, each different row represents a different decision (or sequence of decisions) that can be made by the first player. In turn, each possible decision (or sequence of decisions) that can be made by the second player is assigned to a different column. The resulting matrix constitutes all possible combinations of decisions that can be made when each player selects individual decision strategies. Each cell of the matrix then contains a set of two values, each representing the individual payoff for each player. The left value indicates the payoff for the first player, while the right value indicates the payoff for the second, with higher values implying a more favorable outcome. The payoffs for each player need not be equal, and determining appropriate payoff values for each cell plays an important role in creating an accurate model of the situation to be analyzed. Many different games can be displayed using the normal form, and discussing an example game such as the Prisoner's Dilemma will better illustrate the typical format and meaning of a normal form game.

Player 1 \ Player 2	**Defect**	**Silent**
Defect	-4,-4	-1,-5
Silent	-5,-1	-2,-2

Prisoner's Dilemma - Table 1

The Prisoner's Dilemma is a classic game that models the following situation:

Imagine two coconspirators are arrested for suspected robbery by the police. These two individuals did in fact commit the crime, but the police don't have enough evidence to pursue anything beyond petty theft. Unfortunately, petty theft only incurs a two-year prison sentence. However, with incriminating testimony from their partner in crime, the police can pursue a five-year sentence on the suspect instead. As an incentive to cooperate, the police offer each suspect a one-year reduction of any prison time incurred if they will defect against their partner rather than remain silent. Each suspect is placed in a different room and asked to make their decision without knowing the decision made by their partner.[26]

Table 1 models this classic game, and the best decision strategy for each player may be surprising. Looking at the matrix it can be argued that the most desirable outcome for the suspects is to both remain silent and serve their two years, yet when each player tries to make a decision based on how the other player might act, this does not appear to be the best strategy. If player one assumes that player two will defect, then player one should look at all options under player two's defect column and select the one with the highest payoff (the shortest prison sentence) as his decision. Since remaining silent will incur a five year sentence, and defecting will shorten that to four years, then player one's most rational choice is to defect should player two defect. But what if player two remains silent? In that case player one will receive a two year sentence for remaining silent as well, but only a one year sentence for defecting. Therefore if player two remains silent, player one's most rational choice is still to defect and shorten his sentence by one year. This means that regardless of the choice made by player two, player one's best choice is always to defect and shorten his sentence. As one

might expect this also applies to player two, and one can see that the best choice for each player is to defect even though it means a larger four year sentence for each player than the two year sentence they would have each gotten for remaining silent. The dilemma in this situation is that one player can not control the decisions of the other player, and therefore must select his decision strategy to account for any possible decision made by the other player. Using a review of classic game models, the normal form as described above, and the previous discussion of Chinese economic policy, a more complex game that simulates the economic interaction between the United States and China can be created.

Before moving on to the design of the game, it is worth addressing several limitations and criticisms of game theory. First, a common criticism of the Prisoner's Dilemma as described above is that it does not take into account the cost of moral injury to a suspect that betrays his partner by defecting (or perhaps also the physical injury should the suspect be a member of an organized crime outfit such as the Mafia). Similarly, elements of human behavior such as revenge and altruism may be disregarded by the game designer and not properly reflected in the game.[27] To account for this, the payoff values for each decision could be reduced or increased by any associated moral cost or benefit, and doing so might significantly impact the payoff of a decision and ultimately alter the best strategy for a player. Therefore, the analysis that follows will attempt to openly discuss any premise or assumption that is made with regard to moral costs or benefits. By design, intangible costs related to emotion, politics, morals, or culture will only play a role in the game if their value is integrated into the rules of the game, and therefore the analysis will attempt to include these costs when obvious and reasonable. Second, the payoffs encoded must reflect perceived payoffs from the perspective of the players, rather than the actual payoffs received. Players make strategy

decisions based on what they know at the time the decision is made, not what historians and researchers discover about outcomes from the body of literature generated after the fact. This makes game theory analysis a much more difficult tool to use in retrospect, as outcome bias could shape the researcher when selecting appropriate payoff values. In this case, the focus is on current and future strategies of the United States and China, providing some level of mitigation for this bias. Finally, game theory breaks down when dealing with irrational actors. A premise of game theory is that players will always select the strategy that provides them the greatest utility. This will ultimately imply that the outcomes which maximize payoff will always be selected, since all associated costs both tangible and intangible will have been considered when selecting the payoff value. However, humans and the systems in which they participate do not always act rationally. The best that can be done in this situation is assume that if the risk is great enough, then rational actions will prevail since the cost of irrationality is simply too great. In fact, this is not a bad wager as games modeling the Cuban Missile Crisis prove quite effective at forecasting the actual outcome of the conflict.[28] With this in mind, the design of the game can be discussed.

Design of the Game

Using only a single, classic game (e.g. The Prisoner's Dilemma) as the sole basis of a game intended model the full range of interactions between two global powers would be inadequate. Therefore, to find a starting point in attempting to model something so complex, the author considered multiple game theory models that in some way parallel a decision strategy being employed by either US or Chinese foreign policy. Each of the following

models represents either part of a potential strategy present, or a strategy that must be considered even if it has yet to be observed in current events:

The Tragedy of the Commons. This theory describes the decisions made by a group of individuals that share a common resource. In the classic example from an essay by Garret Hardin, the commons represent publicly available land that can be used by any local farmer to graze his animals. In this scenario any individual farmer is better served to graze his or her animals on this common land instead of his own, freeing up his own land to be productive in other ways such as growing crops. However, the more farmers that take advantage of this common land, the less productive it will be for each individual. In fact, even if the total yield of the commons could be maximized by each farmer showing restraint in use of the commons, the individual motivation to maximize personal yields will take precedence. This quest for individual over group gain also manifests itself in the Prisoner's Dilemma as previously discussed. If a parallel is drawn between the "commons" and underdeveloped countries where infrastructure investment is profitable, then this theory can correlate to the design of the game.[29]

Blotto Game. In this model, each player starts with a group of workers and is presented with a collection of fields that can be worked. The player that assigns the most workers to a given field gains exclusive control of that field, and any workers assigned to that field by the other player are lost. The object of the game is to gain the most number of fields. In the pure form of the game, worker placement decisions are made by each player in secret and revealed simultaneously. By slightly modifying this game to say that worker placement decisions can occur sequentially based on the observed placements of the opposing player, it becomes more applicable. Of note, this very closely parallels the rules for the ancient game of

Go. China has already outlined where it intends to invest, and has already "placed workers" in some "fields" in the design of this game.[30]

Stag Hunt. In the Stag Hunt, two players must decide whether they arrive at a hunting ground prepared to hunt for either a stag or a rabbit. A rabbit may be hunted by a single player, while hunting a stag requires participation by both players. If a player arrives ready to hunt a rabbit then he will be successful in his hunt yet receive only a small payoff. On the other hand, if both players arrive ready to hunt a stag they will each receive a large payoff. However, should a player arrive ready to hunt a stag alone they will go home hungry. This game effectively encapsulates the concepts of trust and cooperation. If both players cooperate they achieve a higher individual payoff than if they work alone; however, they risk receiving nothing if they choose to trust the other player. While China has not necessarily displayed an interest in cooperating with the United States in its Belt and Road initiative, including this game mechanic might reveal it as a dominant strategy.

Hawk-Dove. The Hawk-Dove game can be compared to a game of chicken. If both players are Hawks they both experience heavy loss as they crash into each other, while if both players choose Dove they each experience a slight gain for avoiding the conflict. However, should one player choose Hawk and the other choose Dove, the Hawk player gets a modest payoff for being aggressive while the Dove sustains a modest loss for being passive. The principle strategy in this game is for the player to base his decision on what his opponent has chosen. In essence, if the opponent has already chosen Hawk it is in that player's best interest to choose Dove and avoid a heavy loss. However, if the other player has chosen Dove then a player should choose Hawk to take the modest payoff. Initiative plays an important role in this

game, and a variation of this game will be used to represent the potential use of military force between China and the United States.

Mutual Destruction. When considering a Hawk-Dove game where a potential outcome is mutual desertion of both players, additional nuances must be considered. Initiative becomes even more important, and the credibility of the threat the other player poses also becomes significant. In a game theory review of the Cuban Missile Crisis, the most likely outcomes become either one side backing down to avoid further escalation by the other, or both sides backing down after having to each pay some mobilization costs. This theory will be modeled and used as a sub-game to represent military conflict.[31]

Sequential and Multistage Games. Many of the games discussed to this point require players to make a single decision without knowing their opponent's decision. However, real world situations allow for sequential actions by players and multiple decisions. This analysis will therefore design a multistage game that involves sequential actions by each player. This will allow for a more thorough examination of possible strategies each side can take when faced with multiple actions by the other player.[32]

The US - China Game Model

Proposed Game Rules. Using the above discussion on Chinese and United States policy and the classic games discussed with relevant game elements, the rules of the game will be modeled as follows:

Payoff - In line with the Tragedy of the Commons and the Blotto game, each potential country where BRI infrastructure could be developed will be treated as a "resource field" with a maximum payoff of ten if the player has an uncontested monopoly on investing with that

nation. The value of ten is arbitrary, but other payoff values will be based off of this relative value. Assuming that both the US and China will have equal payoff for the same investment in a given nation is a bold assumption, but making this assumption initially will produce a "core" game involving a generic investment. This core game can then be tailored to each specific nation in order to discover a nation-by-nation strategy. Since a nation-by-nation approach is beyond the scope of this analysis, potential considerations for such a specific approach will be covered later when discussing game variations.

Join - A player may offer to join and cooperate with the other player, sharing the current payoff value. Both players must choose to cooperate for the venture to be accepted. Adding this choice includes elements of the Stag Hunt into the game. This choice represents China and the United States agreeing to work together in fair trade agreements for mutual benefit.

Compete - If a player chooses to compete then that player will attempt to take all of the payoff by entering a sub-game of economic competition. This mechanic adds elements of the Blotto game and the Hawk-Dove game, where players attempt to deny payoff to the other player while gaining more for themselves. For each player that attempts to compete with the other, the total payoff of that "resource field " is reduced by four points as the players Undercut each other for market share. This choice represents either China or the United States attempting to exclude the other from trade agreements with potential for an economic trade war.

Escalate - Players also have the option to escalate and enter a sub-game of military escalation. The player defending against escalation will have the option to Backoff by paying ten points to the aggressor, or can Answer with their own mobilization of forces. If the

defending player Answers, then both players must select to either go to War or Retreat. If both players choose Retreat, then they each pay a 5-point mobilization cost. If either player chooses War, then both players pay 100 points in mutual destruction costs. This interaction greatly simplifies crisis escalation, but parallels work done by Schelling when analyzing mutually assured destruction. This model meets the need for an examination of choice in military escalation.[33]

Resign - The fourth and final choice a player can make is to resign. If a player chooses to resign that player forfeits the current payoff value to the opponent.

Assumptions. Several assumptions are made in the design of this game. First, it is assumed that United States will use military action to defend the economic interests of America if necessary. The same assumption will be made for China in defense of Chinese economic interests. This does not imply that military action would be the first option in defense of economic interests, only that economic tensions could eventually escalate to the point that military action becomes rational and justified. Second, it is assumed that China believes the United States will not back down from a military conflict. Conversely, the United States believes China will back down from a military conflict. This assumption is based on the perceived military strength of each player. Third, it is assumed that China and the United States have roughly equivalent cost and payoff values for the choices they make in the game. This assumption is made in an effort to keep the game generic rather than specific. Finally, the United States was not given a discount for being a recognized reserve currency, nor was China given a discount for cultural similarities they may hold with potential investment countries. These assumptions help keep the game clean, simple, and in agreement with the principle of Occam's razor.

With the game rules defined, the normal form of the game is as follows:

China \ US	Join	Compete	Escalate	Resign
Join	5,5	0,6	Escalate Sub-Game	10,0
Compete	6,0	Compete Sub-Game	Escalate Sub-Game	10,0
Escalate	Escalate Sub-Game	Escalate Sub-Game	-100,-100	10,0
Resign	0,10	0,10	0,10	0,0

US - China Main Game Model - Table 2

Each row represents a different choice made by China, and each column represents a choice made by the US. Each cell indicates the results of the strategy chosen by each side, and the resulting payoff for each player is listed in that cell. The left value in each cell indicates the payoff for China, and the right value indicates the payoff for the US. If both players choose Join, then they share the payoff equally at five points each. If one player chooses to Compete while the other chooses to Join, this takes the form of the Blotto game where the competitor takes the full remaining payoff, but must still pay compete costs. If a player Resigns, then that player forfeits the entire ten point payoff to the other player, unless both players Resign in which case neither receive a payoff. If both players choose the military Escalate option, then mutual destruction is assumed with a resulting -100 payoff. Each remaining cells is a situation where either an economic or military sub-game will be played. The competition sub-game is only played if both players chose to Compete for the payoff, while the escalation sub-game is played when one player choses to Escalate in response to the other player's attempt to obtain a payoff. The normal form for each of these sub-games is as follows:

Aggress \ Defend	Answer-Retreat	Backoff-Retreat	Answer-War	Backoff-War
Retreat	-5,-5	10,-10	-100,-100	10,-10
War	-100,-100	10,-10	-100,-100	-100,-100

Military Escalation Sub-Game - Table 3

China \ US	Undercut	Cede
Undercut	1,1	6,0
Cede	0,6	0,0

Economic Competition Sub-Game - Table 4

The military escalation sub-game has four strategies for the defender and two strategies for the aggressor. Each column in the matrix represents a potential decision strategy for the defender, who gets to make the first move after escalation by the aggressor. Each row represents a follow on decision by the aggressor, which is important if the defender chooses to Answer. Of note, there are several decision strategies for each player that could lead to mutual destruction.

The economic competition sub-game gives each player the option to either Undercut the other player to remain in competition, or Cede the payoff to the other player. When both players compete, the result is an 8 point reduction in payoff while they each take half of the remaining 2 points of market share remaining as payoff. In essence, competition minimizes profit margins for the investors to the benefit of the country where infrastructure is being developed.

With the main game and multiple sub-games defined, they can now be analyzed and integrated. What these models show are all possible decisions that can be made following the criteria that were outlined in the design. Game theory strategies can then help determine the best decision strategy for each player.

Analysis of the Game

In order to properly analyze the main game, the best strategy in the sub-games must be determined and inserted into the main matrix. There will be two analysis strategies to accomplish this: Iterative Elimination of Dominated Strategies (IEDS) and finding Nash Equilibriums.[34] In an IEDS there is an initial check to ensure no decision strategy is clearly dominated by another strategy. If one strategy by a player *always* yields a lower payoff than another strategy regardless of the opponent's choice, then that strategy is said to be "dominated" and should be eliminated. A strikethrough will represent a strategy eliminated because it was clearly dominated by another strategy. Then to find potential Nash Equilibriums, for each opponent strategy the best strategy for a player in response is selected. Player One's best options will be underlined, and Player Two's best options will be bolded. Once all games have been analyzed, any strategy that is both underlined and bolded would be considered an equilibrium point. Furthermore, an equilibrium point that is not struck through should be considered the "best strategy" for both players to select by definition. With this in mind, analyzing both the military escalation sub-game and the economic completion sub-games results in the following:

Aggress \ Defend	Answer-Retreat	Backoff-Retreat	Answer-War	Backoff-War
Retreat	**~~-5,-5~~**	10,-10	-100,-100	10,-10
War	-100,-100	**10,-10**	-100,-100	-100,-100

Analyzed Military Escalation Sub-Game - Table 5

China \ US	Undercut	Cede
Undercut	**1,1**	~~6,0~~
Cede	**~~0,6~~**	~~0,0~~

Analyzed Economic Competition Sub-Game - Table 6

The results of the analysis show that each sub-game has a pure Nash equilibrium - those cells that are both bold and underlined. Specifically, in the military sub-game the aggressor will Escalate conflict initially and the defender will Answer in kind, which will be followed by both parties electing to Retreat and demobilize while paying a 5 point cost in the process. In the economic sub-game both parties are better served to Undercut each other and obtain only a small market share instead of Cede all payoff to the other player. Now these best strategy outcomes can be inserted into the main table, and the same analysis strategy applied:

China \ US	Join	Compete	Escalate	Resign
Join	5,5	**0,6**	-5,-5	10,0
Compete	6,0	**1,1**	-5,-5	10,0
Escalate	-5,-5	-5,-5	-100,-100	**10,0**
Resign	0,10	0,10	0,10	0,0

Analyzed US - China Main Game Model - Table 7

Integration and analysis of the main game model shows that while there are no dominated strategies for either player, there is a single pure Nash equilibrium.

Discussion of the Game

After conducting an IEDS and Nash equilibrium analysis on the model game, the results show that not only will there be a tendency for competition over the payoff, but it is also the best strategy available to each side. While it is tempting to consider cooperation as the most beneficial prospect for both sides, the allure of potentially securing a greater market share through competition appears to take precedence. The true beneficiaries in this situation if both the US and China adopt the Nash equilibrium strategy of competition are the developing countries that realize the cost savings of competing market prices.

Another interesting take away is the irrelevance of military power after reaching the threshold of mutual destruction. All assumptions about military power and which side assumes the other will back down are moot, as regardless of the escalating party the Nash equilibrium shows that the result will be a retreat and demobilization of both parties. Considering that such mobilization is counter productive to the original goal of investing in the infrastructure of developing countries, both parties will effectively avoid military conflict. However, this result could change depending on the assumption that the United States is willing to back the economic interest of American companies with military force. In its capitalist economy, US businesses are privately owned or publicly traded with the government only involved in regulation. This separation of economy and government might imply a

weaker link between the military and economic instruments of US national power. On the other hand, China's socialist market economy provides the government more direct control over Chinese businesses. This greater level of economic control may achieve more unity of effort when shifting to military escalation. In this situation, something that would provoke a military response by China may only result in a bankrupt sector of business in the US. It certainly highlights the important implications of having a strong link between the economic and military instruments of national power.

Returning to the "real world" for a moment, it does seem that China is following the best strategy based on the results of the analysis - to compete for infrastructure projects. However, it would not seem that the United States is doing the same. Rather than compete with China for the investments, the United States is instead relinquishing the investments to China while attempting to raise awareness of the potential for predatory lending.[35]

Variations for Future Games

Future variations on this game should include situations in which either China or the US elects to avoid a certain strategy for reasons not motivated by economic outcomes. For instance, the game could include an option where the US doesn't wish to compete for infrastructure projects in a certain region because of cultural differences. Furthermore, the game could change drastically if each player is assigned a different competition cost rather than the costs being assumed to be equal.

Another variation as mentioned before is to make the game more tailored for a specific country or region where development is to occur. It is a reasonable assumption that China and the US could expect different payoffs the further the distance from the nation being developed.

Adding payoff decay to account for this would allow for more specific forecasts and a better analysis of the best strategy for each party.

Finally, it may be worth exploring the nuance between a social market economy and a capitalist market economy. The military escalation sub-game used in this study assumes that the United States would back American based companies with military force in the event of an economic crisis. Since both countries can reasonably assure mutual destruction of the other, both would avoid a military conflict. However, if American companies are viewed by China as not having the full support of the United States military, perhaps a different escalation sub-game would be more appropriate.

Conclusion

By reviewing both Chinese and US economic policies and discussing the benefits of economic influence, one can see that China is on track to become the world's largest economy. This discussion led to the development of a game model that displays the possible strategies each nation can adopt in economic interaction, and the analysis of the results may have answered some of research questions initially posed. The question of if the United States is executing a sound strategy in response to China's economic activities may have been partially answered. Assuming infrastructure development realizes at least some economic gain, it seems that China is executing a good strategy by competing for economic investments. However, the United States seems to be executing a sub-optimal strategy according to the analysis. The optimal strategy for each party is to engage in economic competition to the benefit of the developing countries. Instead, the United States has adopted a diplomatic policy of trying to increase awareness by warning developing countries of China's unfair lending

practices. If these warnings go unheeded, the outcome is similar to that of the United States either ceding or relinquishing the investments to China. Meanwhile, China continues to steadily invest its excess GDP and manpower in developing countries, further integrating itself into the global world market. Assuming this analysis is correct one can expect the result of the long-term economic interaction between China and the US to be characterized by competition over the favor of developing nations for infrastructure development, coupled with information campaigns and economic actions short of military engagement, which discourage developing nations from working with the opposing nation.

Notes

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