Major power wars: a model based exploratory analysis

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Abstract

Major power wars, like World War II, are wars fought among major powers. They result in enormous destructions, but their root causes remain largely unknown. Ample theories are available trying to explain the origins of major power, but the available evidence does not conclusively support any of these theories. In this paper, we explore the origins of major power wars using an Agent Based model. In the analysis, we focus on the claim that major power wars arise out of dissatisfaction of a state with its role among states, in combination with the relative distribution of power among states. It is concluded that both claims constitute a path to major power war, but that the fights among contenders for becoming the major world power are far more prevalent and thus needs to be further explored.

Keywords: Agent-based modeling, Major power wars, Power curve, Foreign policy role

1. Introduction

The deadliest wars in human history are the two world wars in the 20th century (Pinker, 2011). These wars killed millions of people, cost billions of dollars and redrew the world map in a radical way. These wars were principally fought among the most powerful states, in conjunction with multiple smaller allies. These principal states were vastly more powerful than the other states, and will henceforth be referred to as major powers. Wars like the two world wars may therefore be referred to as major power wars. Major power wars tend to be fought on a far larger scale than wars where major powers are not involved on both sides of the conflict. Fortunately, major power wars are fairly rare. In fact, the world has experienced a steady decline in the amount of conflicts and battle-related deaths since the end of World War II (Hegre, Nygård, Strand, Gates, & Flaten, 2011). It can be argued that these wars are black swan events (Taleb, 2007): high impact, low likelihood of occurrence.

The study of major power wars, and war in more general terms, was popularized by the Correlates of War (CoW) project (Singer, 1972) and similar efforts. The CoW database represents one of the most comprehensive attempts at gathering and using data to test a wide range of hypotheses regarding wars and other topics within International Relations. The open source nature of this database allowed for a whole generation of scholars to test their ideas concerning the origins of wars. The use of extensive datasets such as CoW has however produced mixed results. The various datasets provide support for a multitude of theories that can logically not all be true at the same time. This may be the results of the use of dissimilar data, different coding criteria, alternative measurement and operationalizations, and the use of different statistical methods and techniques. In the analysis of the datasets, statistical models commonly are being used for exploring the significance of predictors and key variables for major power wars. These models have however been limited by the very nature of the problem: (1) a large number of potential factors, (2) a large amount of complicated interactions, and (3) a small set of historical cases.

This has contributed to the present situation regarding a confusing set of theories and conflicting evidence. Scholars have thus been unable to agree on the validity of the set of theories represented by the models which provide conflicting and overlapping predictions.

This research, therefore, takes a different, generative, approach. Generative science aims at explaining the emergence of macroscopic societal regularities (Epstein, 1999). Central to this approach in this context is the question: "*How could decentralized local interactions of states generate major power wars*?" To answer this question, we develop an agent based model and implement it in in Netlogo (Wilensky, 1999). In our analysis of the behavior of this model, we focus on the claim that "t*he relative power relations of states, combined with dissatisfaction with the status quo may breed conflict between the status quo hegemon and a contender" (Efird, Genna, & Kugler, 2003).*

The emergence of armed conflict and war has been studied before using agent-based simulation. This research differentiates itself however in a number of critical aspects. First, this effort is not aimed at just traditional realist aspects of the interactions of states but rather aimed at providing a comprehensive exploration of pathways leading to war. In such models, the realist perspective is taken that everything revolves around military power and that states act only in their own interest (Riordan, 2005). Various other models, e.g. (Cioffi-revilla & Rouleau, 2010), have focused on a single school of thought or a single process leading to war, which is not the focus of this research. An additional innovation in this research is the analysis of the consequences of various uncertainties through computational experimentation, which is made possible by the availability of computing resources.

The remainder of this paper is structured accordingly. In section 2, a review of the relevant theories is presented that form the foundation for the agent based model. In section 3, we present a review of earlier agent based modeling work on the emergence of armed conflict and war. In section 4, we describe relevant aspects of the model. Section 5 contains the analysis of the behavior of the model. Finally, section 6 contains the conclusions.

2. Background

Why do major power wars occur among states, especially when viewed in the light of the enormous costs of such wars? A first explanation of the origins of major power wars is the struggle to become the dominant state. When the dominant state feels threatened by a rising major power that may overtake the former in power, major power war may occur (Kugler & Organski, 1989). The specific type of war concerned here is called hegemonic war, in which dominant powers and challengers fight over dominance (Vasquez, 2009). At the point of power transition, conflict potentially arises from the dominant state defending its dominant position and thus waging a preventative war (Vasquez, 2009). Alternatively, when the challenger demands a large role and is denied this, it attacks the dominant state. As the dominant state declines in power and another state rises to power, the latter will be capable of changing the international system, and presumably will be motivated to do so (Vasquez, 2009).

What are the benefits are of being the dominant state, and being recognized as such by the other states? The dominant state is not just the most powerful state, but also requires recognition of other states in order to actually reap benefits from the position. Authors such as Gilpin assume that the most powerful

state in the system, the hegemon, builds an international system to reflect and protect its interests (Gilpin, 1981). Challengers will not attempt to change the system unless the expected benefits of becoming the new hegemon exceed the expected costs (Gilpin, 1981). If a potential challenger does claim a more prominent role, the dominant state is often unwilling to support this claim out of fear for losing benefits (Organski, 1958).

The struggle for dominance over other states was found to comprise of three key aspects. First, **power parity** is a necessary condition for the competition between challenger and hegemon to arise (Lemke, 1997; Tammen, 2006). As long as preponderance in power is in the hands of the hegemon, challengers are extremely unlikely to press their claim (Moul, 2003). At the point of power parity, the challenger will either become the new dominant state or will be defeated by the hegemon.

The second aspect lies in the **power curve** of both the challenger and the hegemon, and where they are located on this curve. The power distribution among states is not a static configuration, as states go through cycles of power (Doran & Parsons, 1980; Doran, 1989). States may experience internal growth, which allows them to rise from obscurity to prominence. Decline is however also a possibility, especially for dominant states. Dominant forces overstretch their empire and often wage wars for defensive/preventive purposes (Lebow & Valentino, 2009). Other states (relatively) rise in power due to realization of unused potential (Baldwin et al., 1980). An illustration of the power curve of a state is presented in Figure 1.

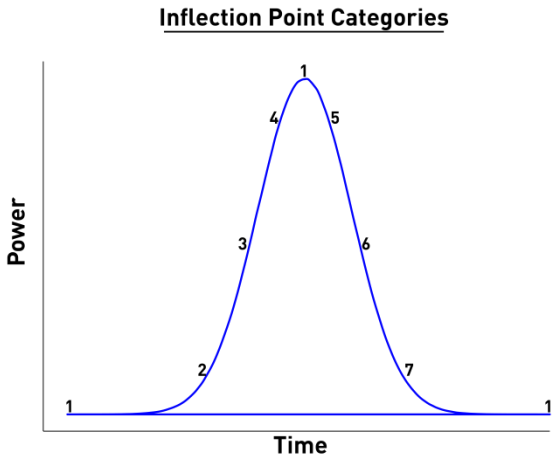

Figure 1: Relative power curve and inflection points

For identification purposes, categories are given to the different positions a state may find itself on the power curve. If a state is rising relative to other states, it would advantageous to fight at a later point in time. If a decline has set in, fighting now is preferential to fighting later. The implications of this are that as long as a hegemon is in category 2, 3, or 4, it is considered not advantageous to fight now. Complementary, once the hegemon starts declining, it will prefer to fight soon, or not fight at all.

The third and final aspect is found in the **satisfaction** of the hegemon and challenger with their current foreign policy role. The hegemon is often the actor that shaped the system and is therefore expected to be satisfied with its role within the system of states. All states have a certain amount of satisfaction with the current world order based on the benefits derived from their role. The hegemon invokes either

positive or negative reactions based on its chosen role (such as hegemonic ruler or balancer). The attitudes of other states vary based on the assertiveness of the hegemon and the nature of the interactions. The challenger is expected to be dissatisfied with the current distribution of benefits from the international system. This dissatisfaction is expected to stem from a lag between a change in power and recognition of this changed power, as shown in Figure 2. War is less likely, however, if the challenging power is satisfied with the existing international order (Kim, 1992). This may explain various peaceful power transitions, such as the Britain-US power transition in the late 19th century. Major power war is thus expected to occur between a hegemon in category 5 and a challenger in category 4, or variations thereof.

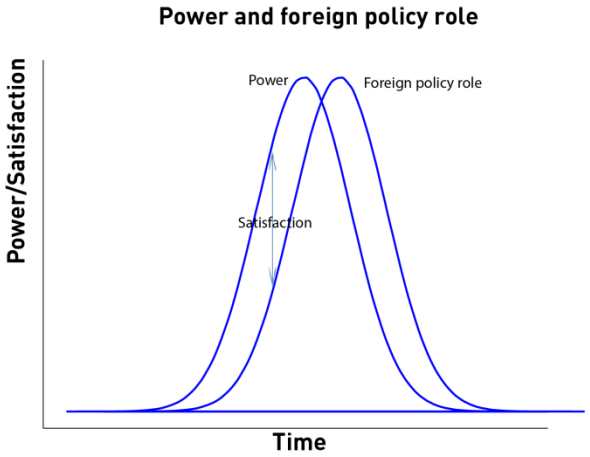

Figure 2: Relative power and foreign policy role

Critiques

Several critiques of these theories are provided by various authors. First, Kim maintains that dissatisfaction with the status quo is a more important indicator of war than changes in the power balance, a finding supported by Lemke and Werner (Kim, 1992; Lemke & Werner, 1996). Kim looks at the causality of power transitions from the reverse perspective, arguing that there is a strong relationship between power parity and dissatisfaction (Kim, 1992). Another potential result of dissatisfaction of a state with its role in the world may be the choice to either balance against the hegemon or to bandwagon with the hegemon. While balancing might increase the odds of war occurring, bandwagoning may prevent major wars (Altfeld, 1984). This choice may allow for similar situations in which war did erupt and war did not erupt. In historic examples both peaceful (e.g., United States-Britain in the nineteenth century) and war-prone power transitions are found (e.g., France-Prussia prior to 1870).

3. Existing models

Arguably the first scientific study to apply a form of Agent-Based Modelling in the study of war was performed by Bremer and Mihalka (Bremer & Mihalka, 1977). Their model was created to test whether or not a balance of power type of arrangement would arise from the interactions of states. They wanted to see if the interactions would lead to a single dominating power. Bremer and Mihalka created a world consisting of 98 states, represented by hexagons. Each of these hexagons is a cellular automaton (Neumann & Burks, 1966). The states in the model are very simplified representations of what a “real”

state might look like. Based on the power variables of states, states are able to take various actions such as forming alliances or waging wars. These alliances can be used to aid them in waging wars. The initial 98 states are transformed through a process of conquest into a world with only a few states that control considerable resources. The authors noticed a tendency for the model to produce similar results in all iterations (Bremer & Mihalka, 1977). The models would almost always result in global domination by a single state. A situation with prolonged existence of small states is unlikely unless the model was heavily altered.

Two groups of simulation models spawned from the work of Bremer and Mihalka. The first, EARTH (Exploring Alternative Realpolitik Theses) is a similar simulator, but developed with a different idea (Cusack & Stoll, 1990, 1994). Rather than attempting to confirm realist theories, the authors set out to prove that even in a realist world, collective action is possible. States can take collective action to enhance their security and avoid being conquered or dominated by a hegemon. (Duffy, 1992) replicated Earth a few years later with a few changes. He introduced parallel initiation of conflicts added perceptual uncertainty. Even though EARTH is virtually identical to the model of Bremer and Mihalka, the authors were able to draw conclusions counter to traditional realist assessments on the basis of the model. They concluded that in a realist world with a relatively high probability of war, cooperation can occur among states.

The second derivative of the work of Bremer and Mihalka is the Geosim simulation framework (Cederman & Girardin, 2005; Cederman, 1994, 2002, 2003). The Geosim simulation framework has been used to study different aspects of war, such as the role of polarity of the world (Cederman, 1994), and the level of security experienced by states (Cederman, 2002). Generally speaking however, it is a direct translation of the model proposed by Bremer and Mihalka, implemented in more advanced software environment. This model of wars is extended in the GeoContest implementation of Geosim (Weidmann & Cederman, 2007). In this extension, states may employ a multitude of strategies that display predatory behaviors, collective security or other strategies.

Quite different from the preceding work here is Sugarscape (Epstein, 1996). It is an agent based model rather than a model consisting of cellular automata. Instead of using strictly economic or power terms, Sugarscape revolves around sugar that is produced per cell on the grid and consumed by the agents. The agents are analogue to real human beings in the sense that they move about, consume a certain amount of resources. They are capable of dying, reproducing, performing combat and more. Within Sugarscape, multiple tribes of agents may exist that have the capability of fighting wars against each other for domination of the world. Depending on the resource distribution, the amount of tribes and their attributes, a variety of outcomes of such wars are possible. War is however not the main focus of Sugarscape and is therefore implemented in a somewhat simplistic fashion.

4. Model Implementation

An agent-based model was created in order to study the behavior of states when waging wars. In this section, a brief overview is given of the model implementation.

Initialization

States are positioned in a grid of squares that represent the landscape in which the states are located, roughly based on Geosim (Cederman, 1994). The squares, deemed provinces, are all assigned to states that own them. These provinces are patches as used in Netlogo, similar to cellular automata (Neumann & Burks, 1966). A few of the provinces are not assigned to any states, but contain water. For every province that doesn't contain water, there is a given population as well as resources and an economy.

Power

Every state possesses a certain amount of power, relative to the other states in the model. The amount of power is calculated through the formula devised by (Chang, 2004) on the basis of 4 aspects of the country. These four aspects are population, provinces owned, GDP and size of military forces. The power is updated every time step, which leads to a power curve over time, as seen in Figure 1. The position of a state on the power curve may be grouped into seven inflection points. Each inflection point indicates a change of sign in the second derivative of the power.

$$Power = \frac{Population + Surface\ area + Economic\ strength + Military\ strength}{4} \quad \text{Equation 1}$$

$$Population = \left(\frac{population_{state}}{population_{all\ states}}\right) * number\ of\ states \quad \text{Equation 1a}$$

$$Surface\ area = \left(\frac{provinces_{state}}{provinces_{all\ states}}\right) * number\ of\ states \quad \text{Equation 1b}$$

$$Economic\ strength = \left(\frac{GDP_{state}}{GDP_{all\ states}}\right) * number\ of\ states \quad \text{Equation 1c}$$

$$Military\ strength = \left(\frac{military\ capabilities_{state}}{military\ capabilities_{all\ states}}\right) * number\ of\ states \quad \text{Equation 1d}$$

Foreign policy role

On the basis of the power of states, they are assigned a foreign policy role. This foreign policy role is based on the expectation of power, based on previous growth patterns. A schematic representation is presented in Figure 2. Satisfaction of a state is based entirely on the difference between the foreign policy role and the actual power.

$$FPR_{Satisfaction} = Power - Power_{expected} \quad \text{Equation 2a}$$

$$Power_{expected} = Power_x * \left(Power'_{\mu}\right)^{t-x} \quad \text{Equation 2b}$$

The expected power is based on the power at a previous point in time (x) multiplied by the mean (μ) growth of power between now and x, raised to the power of the amount of time between now and x (t-x).

Relationships

Three types of ties are present among states. The first relationship is diplomatic. This is based on (Blainey, 1988). Every state has ties to all other states, representing normal diplomatic interactions among states. Part of the relationship is the attitude of the states versus each other. On a scale of 1 through 10, this ranges from hostility (1) to friendship (10). The second relationship is trade. We broadly follow the approach of (Bearce & Fisher, 2003). Trade is conducted among states over trade routes. Trade routes are established if both states see benefit in it. These trade routes allow for trade, which benefits the economies of both states. Additional, if a trade relation is in place, resources may be exchanged to fulfill every state's resource needs. Every state needs to possess every resource present in the model, or needs to have a trade relationship in place with a state that owns the resource. The third possible relationship is an alliance, in which we follow (Smith, 1996). Alliances may be forged among friendly states in order to fight together against a specific enemy. A prerequisite here is that the potential alliance partner has hostile relations with the enemy as well. The alliance decision is made on the expected utility of fighting together against this enemy.

Threats and escalation

Conflicts among states are initiated by the environment of the model. Three specific causes of conflict are taken into account: (1) randomized, with very powerful states experiencing more conflict; (2) on the basis of asymmetric dependence; and (3) very dissatisfied states. Once a conflict is present between two states, both states decide on their course of action. Several options are available to both states, such as escalation, fighting, building capabilities, submission, and more. The combination of the decision of the two states determines what happens: if both states choose the same course of action, this is executed. If different options were chosen, and one of the states is significantly larger, this option is executed. If neither option is applicable, a middle ground is selected between the two options. An example would be if one state chooses to escalate and the other chooses to de-escalate, the sum of the options would be that nothing happens.

Decision making

Decisions by states are made on the basis of maximum utility. The utility of a specific option is determined by the personality of a state and its risk appetite. The personality of the state is comprised of a set of weights for the elements of the utility calculation (Ilachinski, 2004). The elements include items such as expected gains, expected losses, military losses, and loss of trade.

The utility of any action thus is calculated:

$$
\begin{aligned}
&Utility = \\
&w1 * chance_{winning} * expected_{spoils} - \\
&w2 * expected_{losses} * \left(1 - chance_{winning}\right) - \\
&w3 * military_{losses} - \\
&w4 * loss_{of_{trade}} + \\
&w5 * change\ in\ security + \\
&w6 * change\ in\ chance_of_winning
\end{aligned}
\qquad \text{Equation 3}
$$

The expected gains are multiplied by the assessment of the chance of winning; the expected losses are multiplied by the assessment of the chance of loss. This assessment is on a logarithmic scale on the basis of the perceived power of the opponent, as shown in equation 3 (Weidmann & Cederman, 2007).

$$Chance\ of\ winning\ y = \frac{1}{1 + e^{-\frac{(total\ power\ y\ and\ allies - total\ power\ x\ and\ allies)}{total\ power\ of\ all}}}$$ Equation 4

The expected payoffs of any given action are partly based on the expected action of the opponent. Agents perform a basic calculation using their perceived properties of the opponent on whether or not the opponent will choose to fight or do nothing. An example of the payoff matrix that could arise is shown in Figure 3.

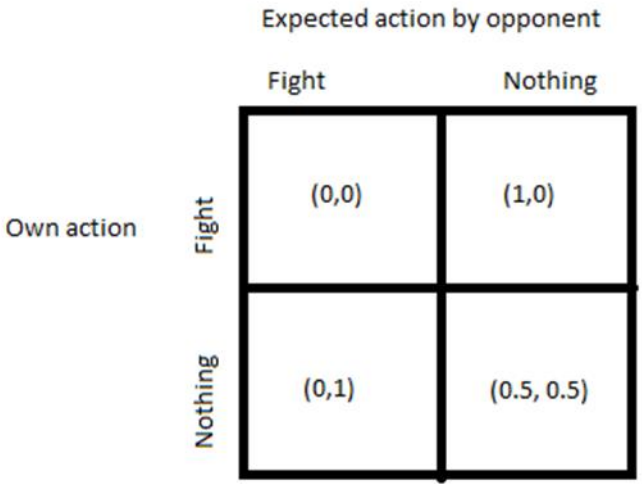

Figure 3: Example payoff matrix

Perceptual uncertainty

States are able to see the capabilities of another state, but only in a bounded fashion. This is also known as perceptual uncertainty. Uncertainty regarding the opponent is based on the amount of previous conflicts, the amount of potential aggressors, and a stochastic function. The amounts of previous conflicts within the memory of state represent the learning effect that may be present (Rosecrance, 1966). Every state has a limited amount of attention that may be paid to a specific (potential) opponent. When there is a multitude of opponents, the state is unlikely to be able to pay enough attention to the opponents to get an accurate picture (Singer & Deutsch, 1964; Waltz, 1979).

$$Accuracy\ of\ perception = normal(\mu, \sigma)$$ Equation 5

In this equation (based on the implementation of (Duffy, 1992)), μ is a model input, typically set at 0. Furthermore, σ is a combination of an input, the ratio of hostile to friendly nations and the length of the conflict memory between the two states at hand. If there is an extensive history of conflicts among the states at hand, there is less uncertainty due to the learning effects of a conflict, and thus the standard deviation is lower.

Waging war

If both sides to a conflict made the decision to go to war, such a war is fought. Fighting here comprises of attrition of forces on the basis of Lanchester equations (Ilachinski, 2004). A state's military forces, which are based on military capabilities and the relative technological advancement of the state, are thus diminished on the basis of the relative size of the opponent's forces.

$$Fighting_{strength} = technological\ advancement * military\ capabilities \quad \text{Equation 6}$$

$$Technological\ advancement = \frac{\frac{GDP}{Population}}{Mean\ \frac{GDP}{Population}} \quad \text{Equation 7}$$

5. Results

In the following sections, experimentation and results of this study are discussed. First, the experimental setup for the model is briefly described. The, on the basis of the research question, the results of the experimentation with the model are discussed in three parts. The focus here lies on the claim that "t*he relative power relations of states, combined with dissatisfaction with the status quo may breed conflict between the status quo hegemon and a contender"* (Efird et al., 2003). As such, the three parts discussed here are: (1) Dissatisfaction of a challenger with the status quo, and a satisfied hegemon; (2) Power parity among the challenger and the hegemon; (3) A declining hegemon and a rising challenger. Finally, the combination of these three elements is discussed as well as surprising findings in the model outcomes.

5.1.Experimental setup

The number of states in the system and the size of the landscape they occupy may be varied, as the modeler desires. However, in order to keep the amount of computing resources required within reason, the decision was made to limit the amount of agents to 25 in a landscape of 41 by 41 provinces.

In order to obtain the data from the model, 1.000 experiments were performed with 10 replications each. Even though more experiments and repetitions would be desirable, time and computing constraints made us decide to limit the amount of runs to 10.000. The amount of replications was set at 10 replications per experiments. An analysis of the potential extra information from a larger number of replications did not weigh up against the extra runtime required. The model runs for 500 time steps. This specific run length was chosen to take into account the warm-up period of the model, which is based on the observation that major power wars rarely occurred before time step 100. The number of major power wars appears to stabilize itself within this period of 500 time steps.

5.2.Satisfaction

The satisfaction of a state with its role in the world is a measure of a state's willingness to take drastic measures in order to change the current configuration of the world. This satisfaction is based on the power of a state and the recognition of this power by other states. It is expected that highly dissatisfied challengers fight the satisfied dominant state over who becomes the dominant state. The satisfaction of major powers when fighting a war is shown in the scatterplot Figure 4. In this plot, a wide variety of

combinations of satisfaction can be found. In red, the cases are indicated that present a satisfied major power fighting against an extremely dissatisfied major power.

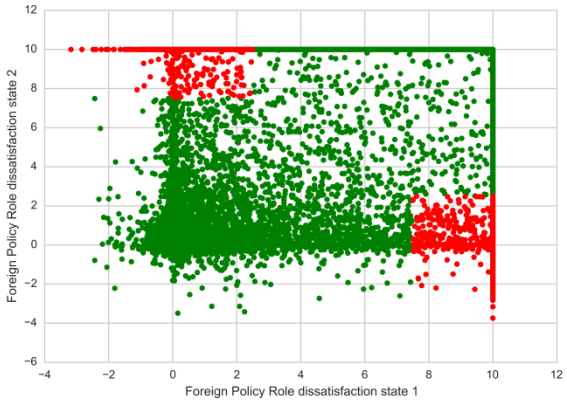

Figure 4: Foreign policy role satisfaction of states
In red, cases with highly dissatisfied states fighting with satisfied states are indicated.

Three specific categories are of importance here:

Table 1: Percentages of cases

Category	Percentage of major power wars
Dissatisfied vs. dissatisfied	68 %
Dissatisfied vs. satisfied	21 %
Satisfied vs satisfied	11%

In the outcomes, there is indeed a large group of cases of satisfied states fighting against dissatisfied states. This group is however a lot smaller than the group of dissatisfied states fighting each other. Considering the hegemon is by definition considered satisfied, these wars are fought among challengers. A possible explanation for this group is that the dissatisfaction has an impact on their risk appetite. If two very risk acceptant states experience a conflict, this may lead to war. As far as the hegemon concerns, fighting is not as appealing, considering the hegemon's low risk appetite.

5.3. Power Parity

Power parity is described as the condition where the power differential among warring states may be considered insignificant. States are expected to only be willing to fight if they perceive the opportunity to win in a military confrontation. The only situation where both states may see the opportunity to win is at approximate power parity. In Figure 5, a heat map is shown of the power of the states fighting in the major power wars. A large "hot" zone is present in the bottom left corner. The cases falling within this hot spot represent conflicts between states, which are more or less at power parity.

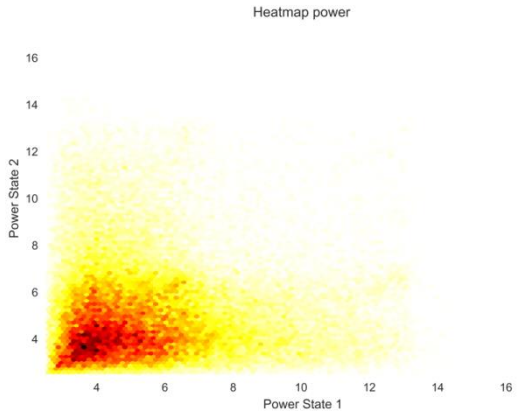

Figure 5: Heat map of power of states

Despite a majority of major power wars occurring at power parity, there are still quite a few cases in which the power differential among fighting powers is quite large. For these cases, Patient Rule Induction Method (PRIM) was used to find the combination of inputs that describes these cases (Friedman & Fisher, 1999). In this analysis, summarized in Table 2, it was found that when the impact of dissatisfaction on risk appetite was very high, major power war could occur under power disparity. An additional relevant input was found to be the weight assigned to expected losses was rather low in these cases. This would make the states far more likely to risk fighting a much stronger opponent. Two final relevant variables were found to be the standard deviation of perception, leading to a larger chance of misperception, and the amount of ideology change per tick.

Table 2: PRIM analysis on power parity

Box	Coverage	Density	Relevant variables	Variables
20	0.65	0.57	1	Impact of dissatisfaction on risk appetite
40	0.3	0.8	4	Impact of dissatisfaction on risk appetite Weight of expected losses Standard deviation of perception Amount of change in ideology per tick

Additionally, in stepthroughs of several cases of wars at major power asymmetry, it was found that the decision to go to war was also based on the expected gains. The expected gains are defined as a percentage of the provinces that the opponent owns. If such an opponent is extremely large, and the risk appetite is very high, this may seem an attractive prospect, despite the high risks.

5.4.Inflection points

The inflection points, as displayed in Figure 1, are an indication of where the state at hand is on its respective power curve. Major power wars are expected to occur rather frequent between a declining state and a rising state. In Figure 6, six histograms are shown displaying the frequency of combinations of inflection points. As may be observed, category 6 did not occur at all and is therefore not representing in the histograms.

As may be observed from all of the histograms, inflection point 4 is by far the most common point at which wars are fought. Unsurprisingly, the most common combination (~ 50%) is two states fighting each

other in category 4, closely followed by categories 2 and 4. The combination of a declining state and a rising state does occur, but only in a small percentage of cases.

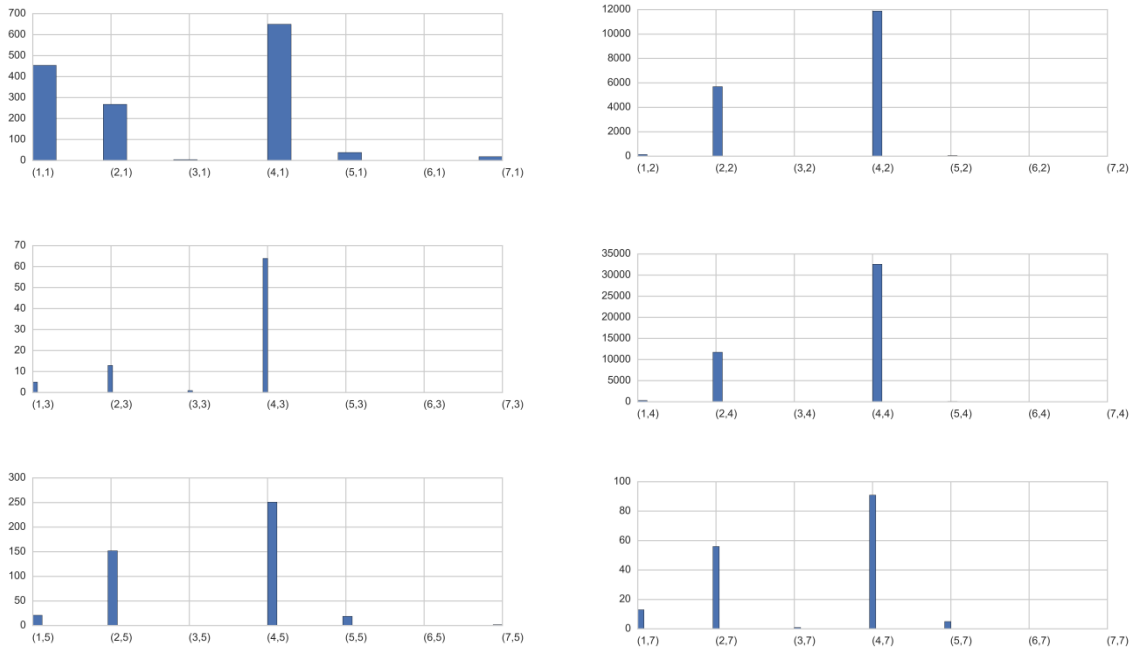

Figure 6: Histograms of inflection points and the frequency of combinations

5.5.Combination

In the previous sections, the individual elements were introduced of a specific path leading to major power war. These three elements are visualized in the figures in the previous paragraphs. The focus here lies on "*the relative power relations of states, combined with dissatisfaction with the status quo".* How does the combination of these three elements contribute to the emergence of major power wars? In the model outcomes, out of 64879 major power wars recorded, 3% of the cases met the criteria. These major power wars were between a dissatisfied and satisfied major power, at power parity at the specific inflection points. This outcome confirms the possibility of this path leading to war, considering the model duplicated an outcome predicted by literature.

Discussion

The model outcomes suggest that the path to war presented by the theory can also be generated by the interactions of agents and therefore may also exist in the real world. It ought to be noted that despite the fact that only 3% of cases contained this path, this does not mean it is equally rare. Due to the uncertain nature of the inputs of the model, the distribution may be skewed. The distribution of inputs based on uncertain and stochastic elements may make certain outcomes especially rare or frequent.

What is interesting, however, is the conclusion that contenders are seen fighting far more often than predicted by the theory. The vast majority of major power wars are fought among dissatisfied major powers at inflection points 4 or 2 at approximately power parity. These cases involve a multipolar world in which two contenders for are fighting while the dominant state remains neutral. These highly

dissatisfied states both want to become the dominant state and are willing to fight wars over it. The possibility of such contenders fighting is barely accounted for within scientific literature. This literature is instead focused on the top and second ranked states fighting. Historic examples are equally sparse, with the exception of the Russo-Japanese war of 1905. Here, two 2nd tier major powers fought for control over parts of Asia that both coveted.

The specific model outcomes may be traced back to the risk appetite of the two contenders. Two highly risk acceptant states are not unlikely to fight each other. The hegemon however is satisfied and less risk acceptant and will avoid war in the model. The question remains why most scholars do not take this possibility into account.

Conclusions

This research aimed at exploring the question: "*How could decentralized local interactions of states generate major power wars*?" In our analysis of the behavior of this model, we focused on the claim that "t*he relative power relations of states, combined with dissatisfaction with the status quo may breed conflict between the status quo hegemon and a contender"* (Efird et al., 2003).

In the model outcomes, the predicted behavior was replicated in 3% of all of the major power wars in the system. This provides a certain measure of validity to the claim that this path to war is a possibility for a future major power war. However, the remaining 97% of major power wars showed different behaviors.

The most surprising conclusion is found in the tendency in multipolar worlds for dissatisfied contenders to fight each other, rather than the hegemon. These states share a high measure of dissatisfaction and an equally high risk appetite. The lack of representation for this theory in the literature makes it worth exploring further, especially viewed in the current multipolar world.

For future research, the model may be used in first instance to explore other paths. The model was set up more broadly than to just investigate the issue at hand, as part of a larger research project. As such, various other claims may be investigated in the model without requiring additional modelling. Additionally, several aspects of the model, such as population dynamics, may be drastically expanded in order to facilitate testing of other claims. In more general terms, the agents themselves may also be made "smarter" in order to create a more realistic agent that represents a state.

References

Altfeld, M. (1984). The decision to ally: A theory and test. *The Western Political Quarterly*, *37*(4), 523–544.

Baldwin, D., Keohane, R., Marion, N., Masters, R., Oppenheim, F., Rosenau, J., … Young, O. (1980). Interdependence and power: a conceptual analysis. *International Organization*, *26*(October 1973), 471–506.

Bearce, D., & Fisher, E. (2003). Computer Simulations of International Trade and Conflict. *Economic Interdependence and …*, *324*.

Blainey, G. (1988). *Causes of War*. Retrieved from http://books.google.nl/books?hl=nl&lr=&id=Mcknp3tt0LMC&oi=fnd&pg=PR7&dq=Geoffry+Blainey,+The+Causes+of+War+&ots=KMPmRLJCed&sig=lb5oSmgA6Lwxfjdnq0PD0lR1FNs

Bremer, S., & Mihalka, M. (1977). Machiavelli in machina: Or politics among hexagons. In K. Deutsch (Ed.), *Problems of world modeling* (pp. 303 – 337). Boston, MA: Ballinger Pub. Co.

Cederman, L.-E. (1994). Emergent Polarity : Analyzing State-Formation and Power Politics. *International Studies Quarterly*, *38*(4), 501–533.

Cederman, L.-E. (2002). Endogenizing geopolitical boundaries with agent-based modeling. In *Proceedings of the Arthur M. Sackler Colloquium of the National Academy of Sciences, "'Adaptive Agents, Intelligence, and Emergent Human Organization: Capturing Complexity through Agent-Based Modeling,.'"*

Cederman, L.-E. (2003). Modeling the Size of Wars: from Billiard Balls to Sandpiles. *The American Political Science Review*, *97*(1), 135–150.

Cederman, L.-E., & Girardin, L. (2005). Exploring geopolitics with agent-based modeling.

Chang, C. (2004). A Measure of National Power.

Cioffi-revilla, C., & Rouleau, M. (2010). MASON RebeLand: An Agent-Based Model of Politics, Environment , and Insurgency. *International Studies Review*, *12*, 31–52.

Cusack, T., & Stoll, R. (1990). Adaptation, state survival and system endurance: a simulation study. *International Political Science Review*, *11*(2), 261–278.

Cusack, T., & Stoll, R. (1994). Collective security and state survival in the interstate system. *International Studies Quarterly*, *38*(1), 33–59.

Doran, C. (1989). Systemic Disequilibrium, Foreign Policy Role, and the Power Cycle Challenges for Research Design. *Journal of Conflict Resolution*, *33*(3), 371–401.

Doran, C., & Parsons, W. (1980). War and the Cycle of Relative Power. *The American Political Science Review*, *74*(4), 947–965.

Duffy, G. (1992). Concurrent interstate conflict simulations: testing the effects of the serial assumption. *Mathematical and Computer Modelling*, *16*(8), 241–270.

Efird, B., Genna, G., & Kugler, J. (2003). From War to Integration: Generalizing the Dynamic of Power Transition Theory. *International Interactions*.

Epstein, J. (1996). *Growing artificial societies: social science from the bottom up*. Brookings Institution Press.

Epstein, J. (1999). *Agent-based computational models and generative social science*. *Generative Social Science: Studies in Agent-Based* (Vol. 4).

Friedman, J., & Fisher, N. (1999). Bump hunting in high-dimensional data. *Statistics and Computing*. Retrieved from http://link.springer.com/article/10.1023/A:1008894516817

Gilpin, R. (1981). *War and Change in World Politics*. Cambridge, UK: Cambridge University Press.

Hegre, H., Nygård, H., Strand, H., Gates, S., & Flaten, R. D. (2011). The Conflict Trap. In *Conference proceedings of the 2011 Annual Meeting of the American Political Science Association* (pp. 1–31). Seattle, WA.

Ilachinski, A. (2004). *Artificial War*. Singapore: World scientific.

Kim, W. (1992). Power transitions and great power war from Westphalia to Waterloo. *World Politics*, *45*(1), 153–172.

Kugler, J., & Organski, A. (1989). The power transition: A retrospective and prospective evaluation. In *Handbook of war studies* (pp. 171–194).

Lebow, R. N., & Valentino, B. (2009). Lost in Transition: A Critical Analysis of Power Transition Theory. *International Relations*, *23*(3), 389–410.

Lemke, D. (1997). The continuation of history: Power transition theory and the end of the Cold War. *Journal of Peace Research*, *34*(1), 23–36.

Lemke, D., & Werner, S. (1996). Power Parity, Commitment to Change, and War. *International Studies Quarterly*, *40*(2), 235–260.

Moul, W. (2003). Power Parity, Preponderance, and War between Great Powers, 1816-1989. *Journal of Conflict Resolution*, *47*(4), 468–489. doi:10.1177/0022002703252980

Neumann, J., & Burks, A. (1966). *Theory of self-reproducing automata*. Urbana, Illinois: University of Illinois Press.

Organski, A. (1958). *World Politics*. New York: Alfred A. Knopf.

Pinker, S. (2011). *The better angels of our nature: Why violence has declined*. New York: Viking.

Riordan, S. (2005). John J. Mearsheimer: an offensive realist between geopolitics and power. *Journal of International Relations and Development*, *8*(4), 381–408. doi:10.1057/palgrave.jird.1800065

Rosecrance, R. (1966). Bipolarity, multipolarity, and the future. *Journal of Conflict Resolution*, *10*(3), 314–327.

Singer, J. (1972). The “Correlates of War” project: Interim report and rationale. *World Politics*. Retrieved from http://journals.cambridge.org/abstract_S004388710000160X

Singer, J., & Deutsch, K. (1964). Multipolar power systems and international stability. *World Politics*, *16*(3), 390–406.

Smith, A. (1996). To Intervene or Not to Intervene. *The Journal of Conflict Resolution*, *40*(1), 16–40.

Taleb, N. (2007). Black swans and the domains of statistics. *The American Statistician*. Retrieved from http://www.tandfonline.com/doi/pdf/10.1198/000313007X219996

Tammen, R. L. (2006). Power Transition and China-US Conflicts. *The Chinese Journal of International Politics*, *1*(1), 35–55.

Vasquez, J. (2009). *The war puzzle revisited*. (C. Reus-Smitt & N. J. WHeeler, Eds.). Cambridge, UK: Cambridge University Press.

Waltz, K. (1979). *Theory of international politics*. McGraw-Hill.

Weidmann, N. B., & Cederman, L.-E. (2007). GeoContest: Modeling Strategic Competition in Geopolitical Systems. *Social Science Computer Review*, *26*(4), 510–518.

Wilensky, U. (1999). NetLogo. Evanston IL: Center for Connected Learning and Computer-Based Modeling, Northwestern University. Retrieved from https://ccl.northwestern.edu/netlogo/