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EXPLAINING THE COLLAPSE OF POLITICAL STATES

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Acknowledgements and Author's Declaration

I gratefully acknowledge the help of my supervisors, Daniel Lawson (Mathematics Department, University of Bristol) and Mark Duffield (Centre for Global Insecurity, University of Bristol) for their patient help and support.

I declare that the work in this dissertation was carried out in accordance with the requirements of the University's Regulations and Code of Practice for Taught Postgraduate Programmes and that it has not been submitted for any other academic award. Except where indicated by specific reference in the text, this work is my own work. Work done in collaboration with, or with the assistance of others, is indicated as such. I have identified all material in this dissertation which is not my own work through appropriate referencing and acknowledgement. Where I have quoted from the work of others, I have included the source in the references/bibliography. Any views expressed in the dissertation are those of the author.

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ABSTRACT

The recent re-emergence of asabiya as an explanation of political cycles (Cliodynamics, 2010) led us to wonder if an alternative explanation could exist; ideally one which does not directly draw upon hard-to-measure social concepts such as asabiya. Our project aims to investigate a model for political cycles within a state that draws upon more measurable units, and allows factions in the state to make rational decisions to maximise their own payoff. We then began to apply this model to civil wars in Africa by adding a term for 'lootable' resources, such as alluvial diamond deposits (Duffield, 2002). We found that, along with the suppressive power of the state, other factors such as the disruption of economic activity in wartime can determine the likelihood and duration of civil war. We also determined that the distribution and relative value of lootable resources can be a key influence in instigating civil wars, although its effects are not necessarily linear.

Contents

1. INTRODUCTION

1.1. AN ALTERNATIVE TO ASABIYA

1.1.1. ORIGINS OF ASABIYA

The fourteenth-century Arab scholar Ibn Khaldun developed a theory to explain political cycles in his native Islamic North Africa. His theory centred on the concept of 'asabiya', which is a form of group solidarity. Ibn Khaldun believed that the formation, growth and decline of dynasties and political factions within North Africa could be explained by the strength of group solidarity (asabiya) at each level of organisation, from families up to feudal lords, nobles and kings. Asabiya is described as a capacity for collective action, and operates at nested levels; as such, a family may belong to a village, and the village to a state. The asabiya of the village depends on the loyalty of its constituent families, their ability to communicate amongst themselves and their willingness to forward the interests of the village, even at personal cost. Similarly, the state depends on the solidarity of its member villages and families. A corollary of this is that the asabiya of the state must be stronger than the asabiya of all its member villages combined, or else it would fall apart (due to the individual ambitions of its members). (Turchin, Historical Dynamics: Why states rise and fall, 2003)

Turchin goes on to describe the dynamics of asabiya in a manner that can be easily translated into a mathematical model. In the Muqaddimah, asabiya is said to arise from "the social intercourse, friendly association, long familiarity and companionship" (Ibn-Khaldun, 1958). Asabiya is said to develop during situations in which co-operation is necessary for survival. Ibn Khaldun uses the examples of the Maghreb tribes living in the deserts of North Africa. For them, desert life was a constant struggle for survival, and so individuals were tied closely to their family or tribe. He contrasts this with the lifestyle of the Arab inhabitants of the coastal cities such as Tunis; their everyday necessities were met through the wealth of trade, and could afford considerations other than immediate survival. According to Ibn Khaldun, luxuries, i.e. anything not strictly required for survival, cause degeneration and a decline in asabiya. This is possibly due to a rise in individualistic aspirations at the expense of the capacity for group action. When every member of a group is looking out for their own personal gain, it is often difficult to convince any of them to make personal sacrifices for the good of the group.

Rosenthal translates Ibn Khaldun's definition of asabiya as 'making common cause with one's agnates', and goes on to say that asabiya confers 'the ability to defend oneself, to offer opposition, to protect oneself, and to press one's claims' (Turchin, Historical Dynamics: Why states rise and fall, 2003) (Ibn-Khaldun, 1958). This begins to address the interaction between groups through asabiya. In Ibn Khaldun's description of the political cycles in North Africa in the 14^{th} century, he ascribes the regular takeover of the 'civilised' peoples of the coastal areas by the tribal warlords of the desert to the natural military superiority of high asabiya over low asabiya groups. Further, he points out that desert dynasties become increasingly mired in luxury and infighting once they conquer richer urban areas, and eventually are themselves replaced by new immigrants from the desert. This fits with his assertion that asabiya reduces in luxurious, civilised surroundings.

1.1.2. LIMITATIONS OF ASABIYA

Outside of 14th century Tunisia, the relevance of the asabiya theory is somewhat diminished. The solidarity-multiplying effect of hardship, among others, does not work as described in many modern nations. In modern Africa for example, rebel movements are increasingly run as businesses, using their original grievances as a convenient front through which they advertise for support (Collier, 2006). This does not fit with the idea that rebel factions emerge as a direct response to shared hardship within a community. Indeed, many rebel fighters choose rebellion as a profession, often for economic reasons. In this case, asabiya seems more a symptom than a cause; perhaps group solidarity has an underlying cause that is more economic than social.

Further, asabiya is a fairly difficult substance to measure. It would be far more convenient to have a model for political cycles that can be fitted to statistics available in modern nations. While Turchin makes the point that many political cycles in history follow the trends described by the asabiya theory, this does not necessarily preclude the existence of a more fundamental phenomenon underlying asabiya. This phenomenon could be based on rational strategies at a group level that aim to maximise utility. If this is the case, then we may be able to identify the utility type and mechanism, providing a more measurable and quantifiable theory.

We initially postulated a theory that the utility that groups choose to maximise is some function of political power within the state and resources. Both these 'currencies of politics' can be measured fairly directly, through votes for factions, and their spending or income levels.

1.2. THE CURRENCY OF POLITICS

If we assume that factions within a state act in their own benefit, then it is essential that we identify the form of utility that the factions attempt to maximise. In the broadest sense, there are only two possible objectives open to factions: material gain, and a more abstract gain in influence. Material gain is easy to describe and quantify; examples of this might be income, capital or access to goods and services. Influence is more difficult, because of its intangible nature. In a democracy, this may take the form of the number of votes controlled by a given faction. However, in dictatorships the number of votes could be entirely irrelevant. Another possibility is a plutocracy, in which political influence is closely tied to the possession of resources. In this case, the two objectives of resource and influence gain are closely linked.

A political state can be understood as a collection of N factions (groups of one or more individuals). Every faction within the state has a choice about whether or not they wish to co-operate with the state. In a stable nation, the vast majority, or indeed all, of the factions choose to conform with the state. Conformity takes the form of a bilateral relationship, in which the faction provides the state with some resources, and the state provides the faction with beneficial services. Peace implies either that all factions are happy with this arrangement, meaning that the benefits provided to them by the state outweigh the cost incurred in supporting the state (analogous to taxation or tribute), or that no faction has the wherewithal to defy the state.

What sort of benefits can a state provide? The most important benefit is security; the ability to defend the citizens of the state and uphold the rule of law. This is of unique importance, and effectively dictates the bounds of a state's sovereignty. Without the ability to enforce itself, through coercion and violence if necessary, there would be no long-term benefit in joining a state, as one would have to live under constant threat of annexation. Further, sovereignty allows for influence outside of a state's borders, and so subscribing to a state could result in increased foreign influence for the member factions. Finally, security mitigates risk, allowing for the development of institutions (Pande & Udry, 2006) and an increase in trade and wealth.

Being within a state also has other trade benefits, as tariffs within borders are usually lower than external tariffs. Further, shared institutions within states could mean lower costs incurred through compliance, and increased transaction speed.

Finally, state provision of public goods can give factions tremendous benefits. This could take the form of infrastructure (e.g. roads, communication and power networks), education or healthcare. However, provision of public goods is not a necessary condition of statehood, although it appears to be a favourable strategy. This is evidenced by the fact that almost all stable governments in the world provide some level of public goods and services.

The other side of this argument is that factions rebelling against the state must have something to gain from doing so. This could be because the taxes exacted from them are too high, provision of benefits is too low, or because the resources of the faction are appropriated or redistributed in a disadvantageous way due to membership in the state. Rebellion offers the possibility of pillage or expansion, especially if the rebelling faction is unusually strong, or its host state is unusually weak.

2. MODEL

2.1. WAR AND PEACE

The interaction between factions during times of peace can be transformed dramatically during wartime. To encompass this observation, our model provides factions with different payoff functions during war and peace.

Peace is defined in this model as a time period during which all factions choose to co-operate. This is effectively the same as saying that all factions subscribe to a single state, choosing to jockey for position through politics rather than violence.

When a faction chooses not to co-operate, it is no longer shackled by its level of political representation within the state, and so can engage in activities solely on the basis of its ability to support those activities using its own resources. However, since it must defend itself and is vulnerable to embargo and coercion from the state, a faction that chooses to rebel also incurs a resource penalty. This may be outweighed by the resources or political power it believes it can capture from other factions during a war.

In our model, factions are faced with a choice of whether to conform with a state or rebel. Conforming factions receive a payoff to both their political power and resources, which is a redistribution among all conforming factions. Rebel factions receive a resource payoff determined by their initial resource productions rate; they effectively 'live off the land' that they possess. As a side effect of conflict, rebel factions can potentially increase their political power[1]. Factions make a choice to conform or rebel based on the behaviour of all factions on the previous time step. Each faction calculates what they would receive if all other factions continued their previous behaviour, and chooses conformity or rebellion based on what it thinks would give it the best short-term payoff.

2.2. UTILITY EQUATIONS

It is worth stating explicitly at this point the difference between lootable (L) and regular (R) resources. Lootable resources can be quickly harvested and turned into capital, even during times of war. An example of this is alluvial diamond deposits. These do not require specialist equipment or expertise to harvest, and can be sold on the black market relatively quickly. Regular resources, on the other hand, represent the main income stream of factions. This can be through farming, manufacture, trade, mining, or indeed any other industry that could be disrupted during wartime. Regular resources are more legitimate, and therefore more visible to the state. As such, they can be appropriated through the political process. Lootable resources tend to be less

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[1] Success in war brings support and influence. This is similar to the explanation of conditions for asabiya increase according to Turchin (Turchin, Historical Dynamics: Why states rise and fall, 2003) and Ibn Khaldun (Ibn-Khaldun, 1958).

reputably obtained, and are consequently less visible to the state. A faction possessing lootable resources has no incentive to reveal them, as it does not require the mechanism of the state to harvest.

Equation 1 to Equation 5 govern political power and regular resource dynamics:

$$\frac{dP^i}{dt} = \left(R_t^i + L_t^i\right)^{\alpha_p}\mu + \kappa$$

EQUATION 1: CHANGE IN POLITICAL POWER DURING PEACE

$$R_t^i = \left(\frac{P_{t-1}^i}{\sum_{j \epsilon C} P_{t-1}^j}\right)\sum_{i \epsilon C} R_0^i$$

EQUATION 2: REDISTRIBUTION OF RESOURCES DURING PEACE

$$\frac{dP^j}{dt} = \left(R_t^j + L_t^j\right)^{\alpha_w}\lambda + \kappa$$

EQUATION 3: CHANGE IN POLITICAL POWER DURING WAR

$$R_t^j = \varepsilon R_0^j + L_t^j - p_w$$

EQUATION 4: REDISTRIBUTION OF RESOURCES DURING WAR

$$\kappa = \frac{\sum_{i \epsilon C} R_i + \sum_{j \epsilon \bar{C}} R_j}{N}$$

EQUATION 5: NORMALISATION CORRECTION TERM

Symbol	Meaning
$\boldsymbol{P}$	Political power of faction
$\boldsymbol{R}$	Regular resources of faction
$\boldsymbol{L}$	Lootable resources of faction
$\boldsymbol{\alpha_p}$	Peacetime exponential (set to 2)
$\boldsymbol{\mu}$	Rate of change during peace
$\boldsymbol{C}$	Set of all conforming factions
$\boldsymbol{\bar{C}}$	Set of non-conforming factions
$\boldsymbol{\alpha_w}$	Wartime exponential (set to 2)
$\boldsymbol{\lambda}$	Rate of change during war
$\boldsymbol{\varepsilon}$	Relative value of regular resources during war
$\boldsymbol{p_w}$	Penalty to resources due to war
$\boldsymbol{\kappa}$	Corrective normalisation term

TABLE 1: PARAMETERS IN MODEL

2.3. Peacetime dynamics

During peace, factions compete for resources through the political system of the state. In a democracy, the political power of a faction can be thought of as the level of representation it has within the state. Political power in our model is a proportion of the total political power in the state, so the sum of political powers of all factions always equals 1.

In the long run, factions that can provide for their people better are more attractive, and so tend to gather more support. This is represented in Equation 1 as a product of a power of the total resources available to a faction with a slow rate constant μ.

The regular resources available to a faction are redistributed at each time step, in a manner proportional to the political power of each faction on the previous time step. This redistribution only occurs between conforming factions, as factions that are rebelling are not able to access the political process peacefully. Lootable resources do not change over time in this model.

2.4. Wartime dynamics

In wartime, the rate of change of political power of factions increases, as the factions have access to more direct methods of coercion. This translates in our model to a value of λ that is much larger than μ.

The redistribution of resources in wartime no longer depends on the political power of rebel factions. Instead, rebel factions use all the lootable resources at their disposal and some fraction of the regular resources in their possession to vie for additional political power. As such, their resources levels are determined only by a linear function of their initial resources. An additional penalty term p_w is subtracted to represent the cost of conflict or suppression by the state. This is currently a constant.

2.5. Choosing to conform

Faced with a situation in which every faction knows the distribution of political power and regular resources, we allow the factions to make a prediction about their future earnings given their decision to conform at the next time step. At every time step, all factions are given information on the current distribution of political power and resources, as well as the previous conformity decision of all the factions. They then calculate R_p and R_w, their predicted resource level in peace and war, by working out what they would get if all other factions repeated their previous decisions and they chose conformity or rebellion respectively.

$$R_p - R_w + k_{choice} + \eta < 0$$

EQUATION 6: CONFORMITY CHOICE EQUATION

If Equation 6 is less than zero, the faction chooses to rebel. Otherwise, it chooses to obey the state and conform. Equation 6 is modified by k_{choice}, which is a small constant bias toward conformity. This could be due to an expected long term payoff from peace, or a hesitancy to engage in conflict[2]. It may well be that this term is zero, but it is interesting to see what effect it has on the outbreak of war. The other term in Equation 6 is η, which is a normally distributed random value with mean 0 and standard deviation σ. This represents error in decision making.

2.6. FITTING THE MODEL

We expect to see a cyclic behaviour in the model, as historical trends (Turchin) show that the fortunes of factions within a state are rarely static. Since we have stipulated a finite and conserved number of factions, the political power and resources of those factions can never fall below 0.

The model should accommodate the possibility of smaller factions rising to overthrow the state. The state is defined as the leading political-power faction, as well as all factions that choose to co-operate with this leader. Leader replacement usually occurs during wartime, as political change accelerates considerably during civil war (Hegre, Ellingsen, Gates, & Gleditsch, 2001).

We chose initial values of political power for all factions to be a non-random broken stick distribution, with faction i receiving 2^{-i} political power, and the N^{th} faction receiving the remainder (total political power sums to 1). A random broken stick distribution was also implemented, but we chose to avoid using this as it is easier to measure the effect of other factors using deterministic initial conditions. The pattern of distribution fits well with observed general election poll figures for many countries, especially the UK (Carr).

Factions were allowed a small amount of randomness in their decision making. This simulates non-optimal decision making- analogous to the trembling hand concept in economics (Selten, 1975).

2.6.1. POWER SHARING

Our model needs to capture the distribution of power observed in modern states. To do this, we used data from general elections in the UK between 1997 and 2010 (Carr) to provide a qualitative view of power distribution.

[2] Due to the natural human desire to minimize risk of death.

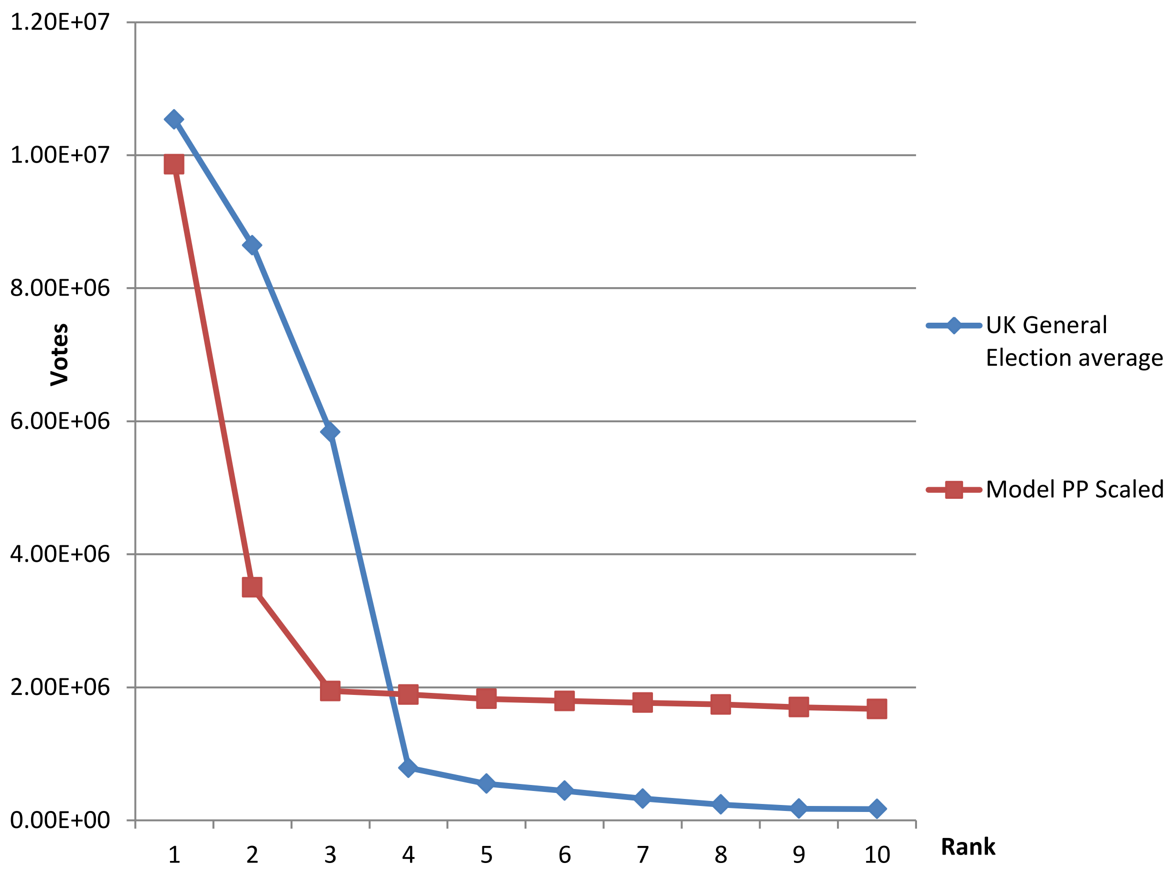

FIGURE 1: POLITICAL POWER OF FACTIONS IN THE UK BY RANK, AVERAGED OVER THE PERIOD 1997-2010 IN BLUE, MODEL PREDICTION OF POLITICAL POWER DISTRIBUTION IN RED.

Figure 1 shows an averaged graph of political power against rank in blue, using data from UK general election results. The distribution that comes out of our model is shown in red, and is scaled to the same total number of votes[3]. By 'rank', we mean whoever occupies a certain position in a list sorted by political power. This is independent of their identity, and so describes the overall behaviour of the system, and says nothing about the performance of any one faction.

The general election data from the UK bears some of qualitative similarity to the model data. They both follow roughly a sharp downward curve, with a rapid drop-off in political power around the 2-4 ranks. There is relatively little difference between all the smaller factions. The distributions level out at different levels, but this may be due to the fact that our model is tailored to African states in which wars are common. Great Britain has been spared armed internal conflict since at least 1746 (Durant & Durant, 1965). By resorting to war, factions may limit their minimum share of power. Also, in a functioning democracy, elimination of weak factions is not possible. This means that the minimum size that factions can reach is much smaller.

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[3] Political power (PP) in our model is given as a proportion of the total. This means that we have to multiply it by the total number of voters in the UK to scale it correctly.

3. METHOD

3.1. GAME THEORY APPROACH

Our method of approaching this problem was to assign a dynamic for the interaction between factions as a set of differential equations. However, it was important that the factions make the choice between war and peace through a rational consideration of the benefits.

Our model puts factions into a repeated game (Fudenberg & Tirole, Game Theory, 1991), however the factions must play simultaneously on each time step, rather than wait to see what the preceding faction does. However, the factions do have access to the history of the game, and can see how other factions played in the past. We chose to implement a choice behaviour with a memory of 1; that is to say that the entire basis of a faction's decision is the situation on the previous timestep. We think this is a reasonable assumption, as rebel factions appear to be more opportunistic than calculated (Collier, 2006). Playing a best response to the recent past is a good way of representing this. It should also be noted that no faction can reliably assess the indirect consequences of its actions, and so does not actively attempt to influence the choices of other players (Friedman & Abraham, 2004).

Factions in our model are also currently designed to be completely myopic (Fudenberg & Levine, The Theory of Learning in Games, 1998). This means that they will always play what they believe to be the immediate best response, rather than actively experiment with responses to get information on how to improve payoff in future play. Also, as discussed above, they do not play sub-optimally to influence the behaviour of other factions.

4. RESULTS

4.1. BASELINE MODEL RUNS

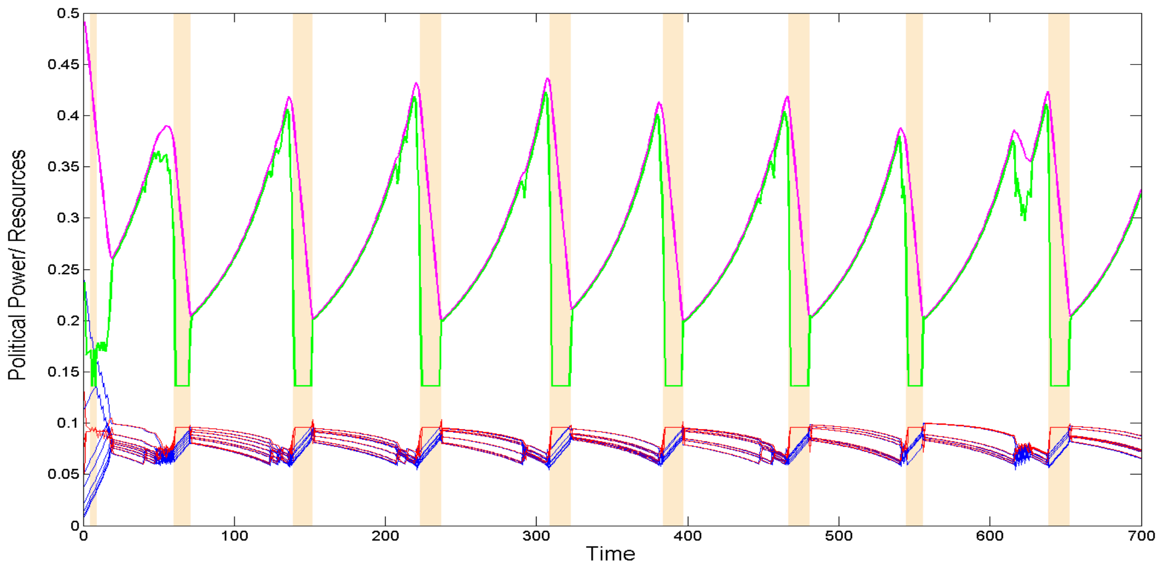

FIGURE 2: MODEL BEHAVIOUR WITH STANDARD PARAMETERS, NO LOOTABLE RESOURCES. STATE POLITICAL POWER IS SHOWN IN PURPLE, STATE REGULAR RESOURCES ARE IN GREEN. THE POLITICAL POWER AND REGULAR RESOURCES OF ALL OTHER FACTIONS ARE SHOWN IN BLUE AND RED RESPECTIVELY. YELLOW BARS SHOW MAJOR WAR OCCURRENCE.

Two of the standard measures used throughout the analysis of our model are 'major war time' and 'average period length'. These can be easily explained using Figure 2. Yellow bars cover every timestep during which there is a major war, i.e. when at least $N - 1$ factions are at war. Major war time is defined as the proportion of the total run time during which major war takes place. A 'period' is defined as the time between major wars. If major war takes place in consecutive timesteps, this is ignored in calculating periods. One convenient way of thinking of average period length is as the average distance between yellow bars.

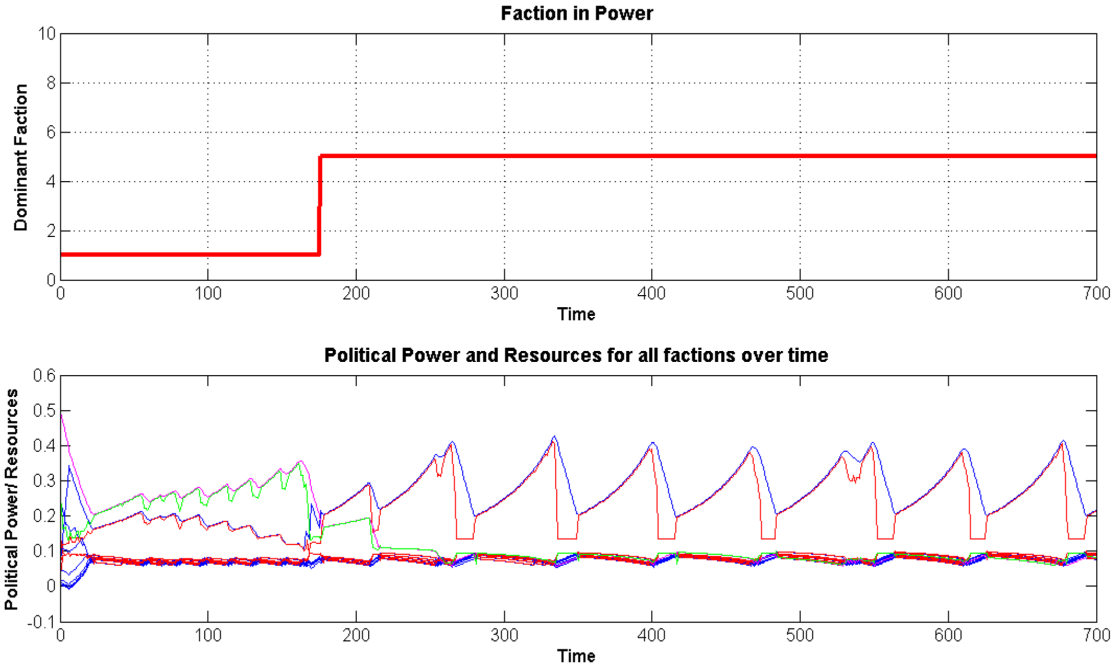

FIGURE 3: STANDARD MODEL RUN, WITH LOOTABLE RESOURCES CENTRED ON FACTION 5. THE TOP GRAPH SHOWS THE MOMENT AT WHICH FACTION 5 REPLACES FACTION 1 AS THE LEADER.

Figure 3 shows a situation in which leader replacement takes place. This is due to the concentrated delivery of lootable resources to faction 5. The transition period between the two epochs[4] is particularly interesting.

[4] Period of dominance by a certain faction.

4.2. WAR PENALTY

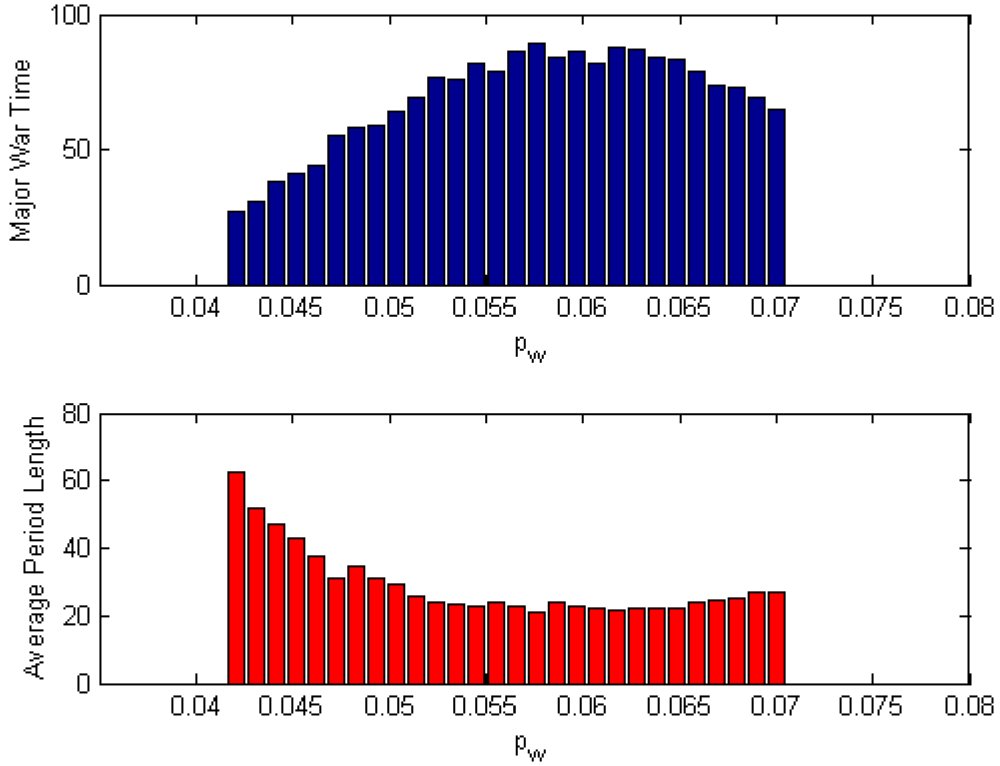

FIGURE 4: EFFECT OF P_W ON THE TOTAL TIME OF MAJOR WARS AND THE AVERAGE LENGTH OF TIME BETWEEN MAJOR WARS

By running the model using a range of values for p_w, we can measure its effect on two relevant measures; namely, major war time and the average length of time between major wars. The range of values was chosen to avoid situations of leader replacement, as these cause inconvenient disturbance. All other variables were set as in the typical model run.

There appears to be a non-linear behaviour in p_w, as evidenced by what seem to be local minima/maxima in the graphs. On possible explanation could be that above a certain magnitude, p_w causes alignment in faction decisions. This hinges on the fact that p_w dissuades rebellion, but what we are measuring is 'major war', in which there are at least $N - 1$ rebellion choices by factions. A very high value of p_w may push many factions into a situation where they are willing to tolerate immense loss of resources in peace, because the cost of war would be untenable. In this case, when the leading faction finally pushes one faction too far, the others are also on the brink of rebellion anyway, setting off a major war. This explanation will take more investigation, but early observations do not seem to contradict it. If this is the case, it would be worth tracking down the locally optimal p_w to find a way of punishing individual rebellion without risking a mass uprising.

4.3. EPSILON

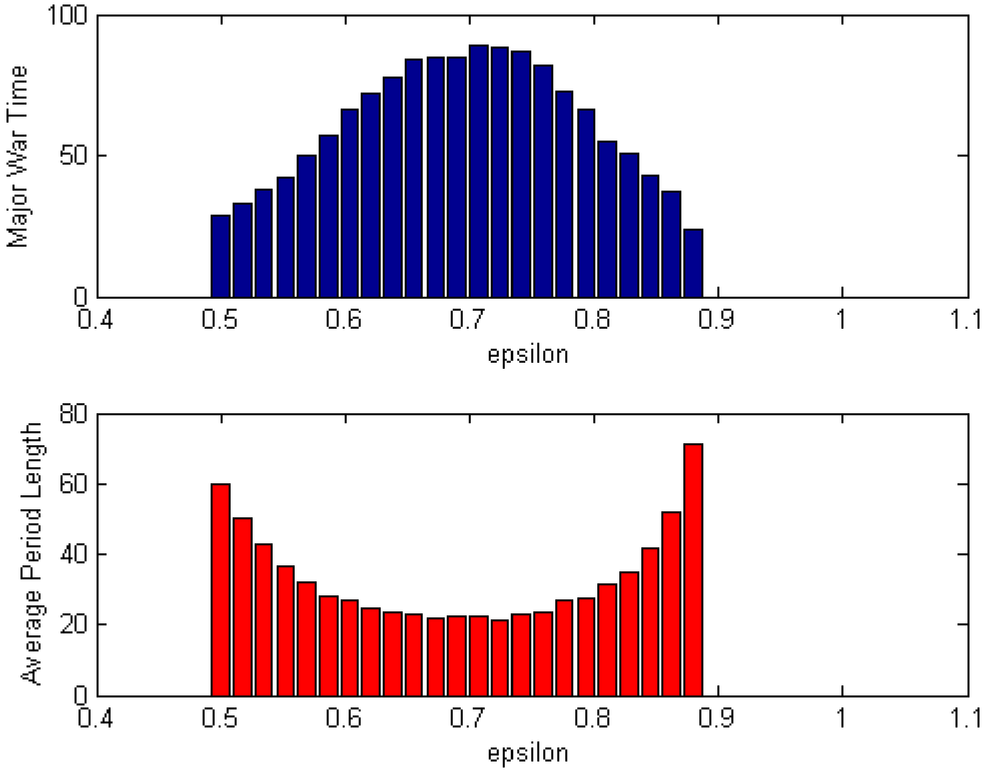

FIGURE 5: EFFECT OF EPSILON ON MAJOR WAR OCCURRENCE.

Using a similar method to analyse the effect of ε on major war time and the length of relatively peaceful periods, we can see a clear local maxima/minima. Again, locating a local optimum could be useful in preventing major conflict in the model. This analysis was done with a fixed quantity of lootable resources, and varying this at the same time may have interesting results. However, this is a very time-consuming task, so will not be attempted here.

4.4. TOTAL LOOTABLE RESOURCES (Y)

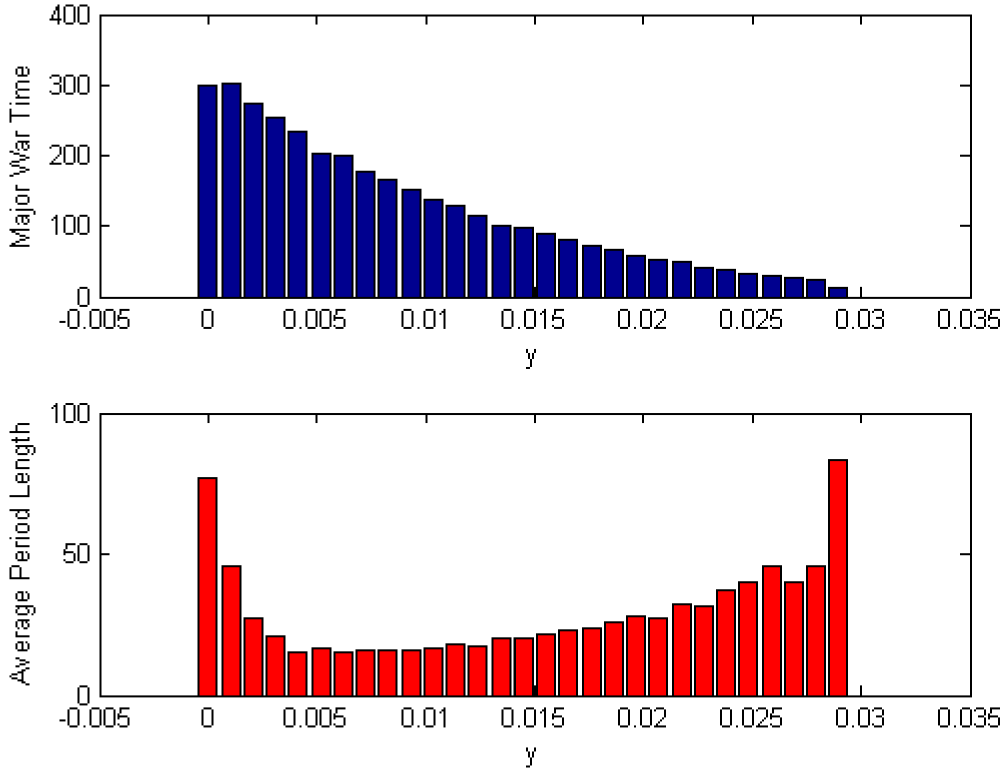

FIGURE 6: EFFECT OF TOTAL QUANTITY OF LOOTABLE RESOURCES IN THE STATE (Y) ON MAJOR WAR OCCURRENCE

The effect of total lootable resources (y) is much more difficult to pin down, as it is closely related to other variables such as z (spread of lootable resources) and ε. Values of y larger than 3×10^{-2} cause instability in the model and unrealistic behaviour. This is not surprising, as lootable resources are pretty much independent of the state in our model, and do not change over time. If lootable resources were prolific, there would be no need for a state[5]; since our model is entirely based on the existence of a state, it is foreseeable that this could cause problems. Further, lootable resources are inexhaustible in the current incarnation of our model, and so must have a very slow 'harvest' rate to make it realistic over long timescales[6].

Lootable resources are awarded to the non-leading factions first in this analysis, and the time spent at war drops considerably as y increases. A possible explanation is that the lootable resources satisfy some of the smaller factions[7], meaning that they stay out of conflicts that they would otherwise get involved in. In this case, lootable resources don't really prevent war, they just prevent it from escalating as easily. However,

[5] The apparatus of the state is unnecessary for harvesting lootable resources, as defined in section 2.2.

[6] In the long run, states and factions receive the bulk of their income from regular resources. Lootable resources may occur in large quantities but are not often available. Averaged over a long time, this becomes a small number in relation to regular resource income, which is available at every time step. Modelling lootable resource 'spikes' is something that could be considered in future work.

[7] They can still receive lootable resources during peacetime

awarding any one faction with too much lootable resources can cause that faction to inevitably become dominant. If it wasn't the leading faction before, then the wars in which it displaces its predecessor will affect both our measures considerably.

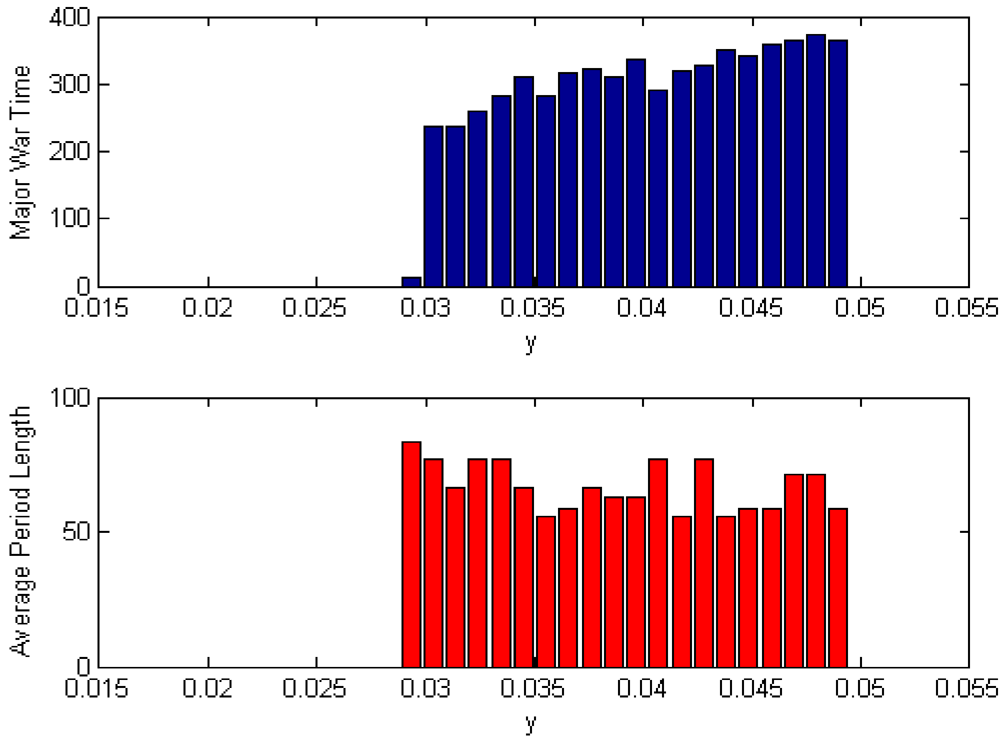

FIGURE 7: EFFECT OF TOTAL QUANTITY OF LOOTABLE RESOURCES IN THE STATE (Y) ON MAJOR WAR OCCURRENCE, IN THE REGION IN WHICH LEADER REPLACEMENT OCCURS.

Figure 7 extends the analysis of y from the point at which leader replacement becomes possible, right up to values at which instability begins to occur. In this region, major war is common, as the new leader faction rises up and holds on to the highest rank.

4.5. ANOVA

By measuring the effect of the parameter models on a single standard measure, we can determine the relative sensitivity of our model to each parameter. Table 2 shows the effect of several of the parameters on the outcome of the model. The standard measure we chose to use was the time spent in major conflict (as a proportion of the total time the model is run). Major conflict is defined here as a situation in which at least $N-1$ factions choose to rebel against the state. In this situation, almost everyone is pulled into the fight, resulting in a time of great upheaval. Since the rebel factions are not necessarily on the same side, so the conflict is not limited to a war against the state.

Parameter	One way ANOVA p-value, Effect on time spent in major conflict
p_w	4.3×10^{-14}
ε	1.4×10^{-14}
k_{choice}	2.4×10^{-22}
σ	0.53
y	1.1×10^{-35}
z	2.8×10^{-10}
λ	1.6×10^{-28}
μ	2.6×10^{-32}

TABLE 2: SENSITIVITY OF MODEL TO PARAMETERS

The p-values in Table 2 tell us how sensitive the model is to each parameter[8]. As such, the closer the p-value is to zero, the more sensitive the model is to a given parameter. Conversely, p-values near 1 suggest little or no sensitivity.

The two final parameters in Table 2 are merely used to check the model is working properly. λ and μ are rate constants, and represent the 'speed of history', i.e. the rate at which other variables change during war or peace. These were needed to embody the theory that political change is quicker in wartime than peacetime. There isn't an obvious way to affect these through policy decisions, so it is probably a fair assumption to say that these remain constant within a given state over a short timescale. If these values had little effect on our standard measure, then there would be something very wrong with the model. Thankfully, the model is incredibly sensitive to λ and μ.

p_w appears to have a very significant effect on the outcome of the model. This is not surprising, as p_w directly penalises factions that choose to go to war, and so by raising or lowering it one can change the likelihood of major conflicts breaking out. Representing a war penalty, p_w appears to do its job by reducing the occurrence and length of major conflict.

ε has slightly less influence than p_w, but it is still very significant. ε runs between 0 and 1, and larger values of ε produce more conflict. ε represents the relative value of regular resources in wartime.

k_{choice} is a bias toward peace in the decision making process factions use. The model is extremely sensitive to k_{choice} so an incredibly small value here can change the model behaviour completely. Increasing the size of k_{choice} reduces the occurrence of major wars.

σ is the standard deviation of the normally distributed random variable (η) in the decision function. This has a p-value greater than ½, and so is fairly unlikely to cause consistent change in the model outcome. This is

[8] More precisely, the p-value represents the probability that a change in the parameter does not cause a change in the standard measure.

probably because however spread out the distribution may be, η is still as likely to be positive as negative. Since η is recalculated for each faction at every timestep, this cancels itself out.

The total amount of lootable resources in the state, y, has an astonishingly powerful effect on the occurrence of major wars in our model. Lootable resources should theoretically increase the likelihood of war, except in the situation in which the lootables are distributed evenly. In an even distribution, the effects from lootable resources should cancel out. Since our model uses a normal distribution term, the chances of producing a perfectly even allocation are negligible, so this should never arise. In practice, we have seen that y can actually prevent major war in some cases too (section 4.4).

The final term we consider in Table 2, z, is the standard deviation used in distributing lootable resources. This appears to have a significant effect on the result, but a smaller one than any of the other variables except σ.

4.6. Multiple comparison of means

To check the relative effect of p_w, ε and y on the model, we used a multiple comparison of means:

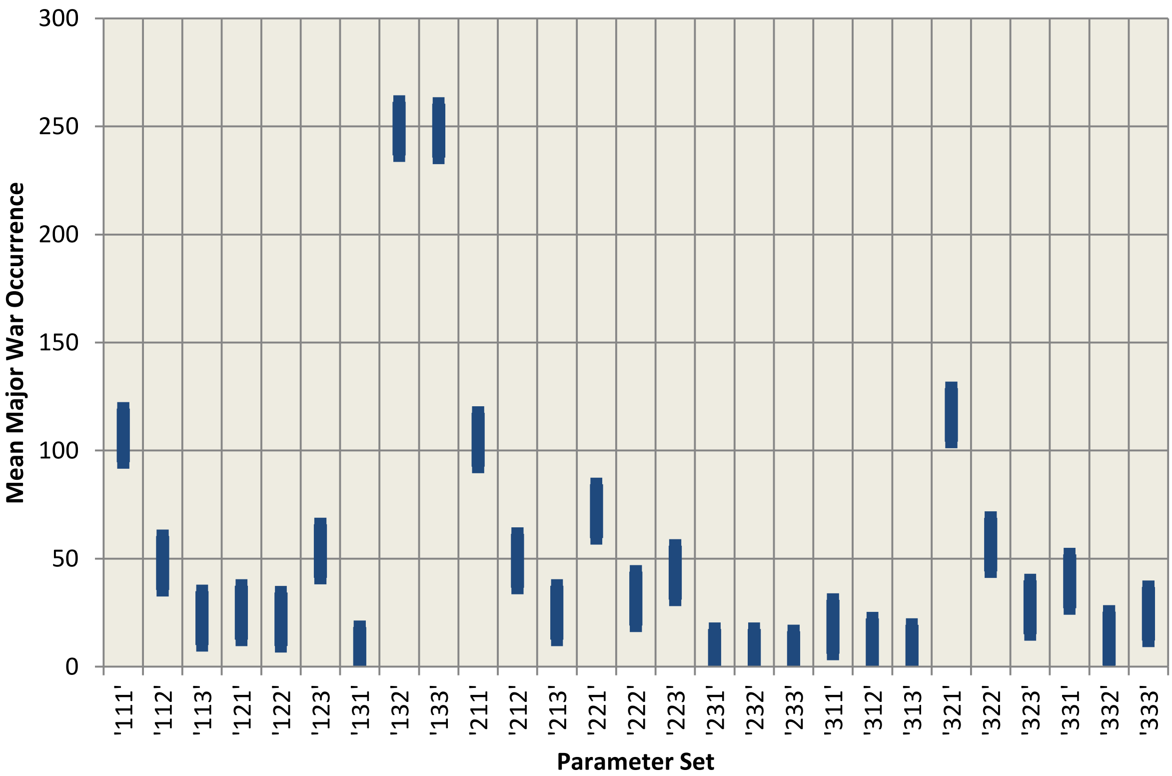

FIGURE 8: MULTIPLE COMPARISON OF MEANS USING FIGURES IN EQUATION 7

$$\begin{bmatrix} p_w = 10^{-2} & p_w = 2.5 \times 10^{-2} & p_w = 4 \times 10^{-2} \\ \varepsilon = 0.5 & \varepsilon = 0.75 & \varepsilon = 1 \\ y = 10^{-2} & y = 2 \times 10^{-2} & y = 3 \times 10^{-2} \end{bmatrix}$$

EQUATION 7: PARAMETERS USED IN MULTIPLE COMPARISON OF MEANS

To do a multiple comparison of means, we used three values for the three most interesting parameters: p_w, ε and y. These had to be tried out in every possible combination, so we produced 27 results, each repeated twice. One value for each parameter had to be chosen for every run, corresponding to choosing one entry from each row in Equation 7. The runs were given 3-digit names corresponding to the choice of parameters, so that the first digit was the choice (reading left-to-right) from the first row, the second digit corresponded to the choice from the second row and so on. As such, run 123 corresponds to the choice $\{p_w = 10^{-2} \quad \varepsilon = 0.75 \quad y = 3 \times 10^{-2}\}$, and the parameters used in our 'standard' model, 333, corresponds to all the rightmost values $\{p_w = 4 \times 10^{-2} \quad \varepsilon = 1 \quad y = 3 \times 10^{-2}\}$.

The mean major conflict times for the runs 132 and 133 are considerably longer than the others. This suggests that the combination of low war penalty and high regular resource income during wars causes the most serious conflict. A moderate quantity of lootable resources also appears to be required as well, since 131 does not appear to be significantly different from the standard 333 run.

5. DISCUSSION

5.1. MATHEMATICAL MODELLING OF POLITICAL STATES

Attempts to describe and understand history have traditionally been limited to verbal theories, but there are a growing number of attempts to construct models that capture the general principles of historical societies (Cliodynamics, 2010).

The great benefit of mathematical modelling in this area is that it lets us identify trends, and compare our theories more directly to empirical data. Further, it may eventually be possible to make limited but meaningful quantitative predictions of future behaviour in certain areas. Quantitative predictions would be a step toward a more scientific framework for history (Turchin, 2010).

Mathematical modelling may also pick up on things that more traditional historical investigation misses. For instance, the analysis techniques of disciplines such as evolutionary biology (Gavrilets, Anderson, & Turchin, 2010) could help to explain cycles in populations much more precisely than verbal descriptions.

5.2. ALTERNATIVE APPROACHES

We considered adding an explicit spatial element into our model, but due to the limited timeframe of this project this was too ambitious. Spatially explicit, agent-based models can be extremely useful in this field, as they more closely resemble the interactions between states. However, since our model chiefly discusses interactions within states, for our purposes the method we used was sufficient.

One interesting approach would be to have ‘clique’ interactions within the state, with factions only being able to interact with some $n \leq N$ number of neighbours. A good starting point for this might be the hexagonal model used in a recent paper by Gavrilets (Gavrilets, Anderson, & Turchin, 2010). However, within-state factional interactions may occur through nested levels, so some hierarchical arrangement of factions would have to be created. Sadly, this would add considerable complication to our model, more than can be justified by the probable benefits at the moment.

5.3. RELATION OF POLITICAL POWER TO RESOURCES

One interesting feature of the model is that political power tends to converge to the quantity of regular resources. This can be seen in Figure 2, in which the state regular resources (green) follows a jagged and disjointed path, which is followed smoothly by the state political power (purple). This suggests that the one crucial variable in the dynamics is the regular resources available to each faction. We cannot dispense with political power, since it still plays an important part in the mechanism of faction interaction; however this does mean that we are justified in our assertion that factions should try to maximise only their regular resources. Their political power, after all, will catch up with their wealth.

5.4. APPLICATION TO AFRICA

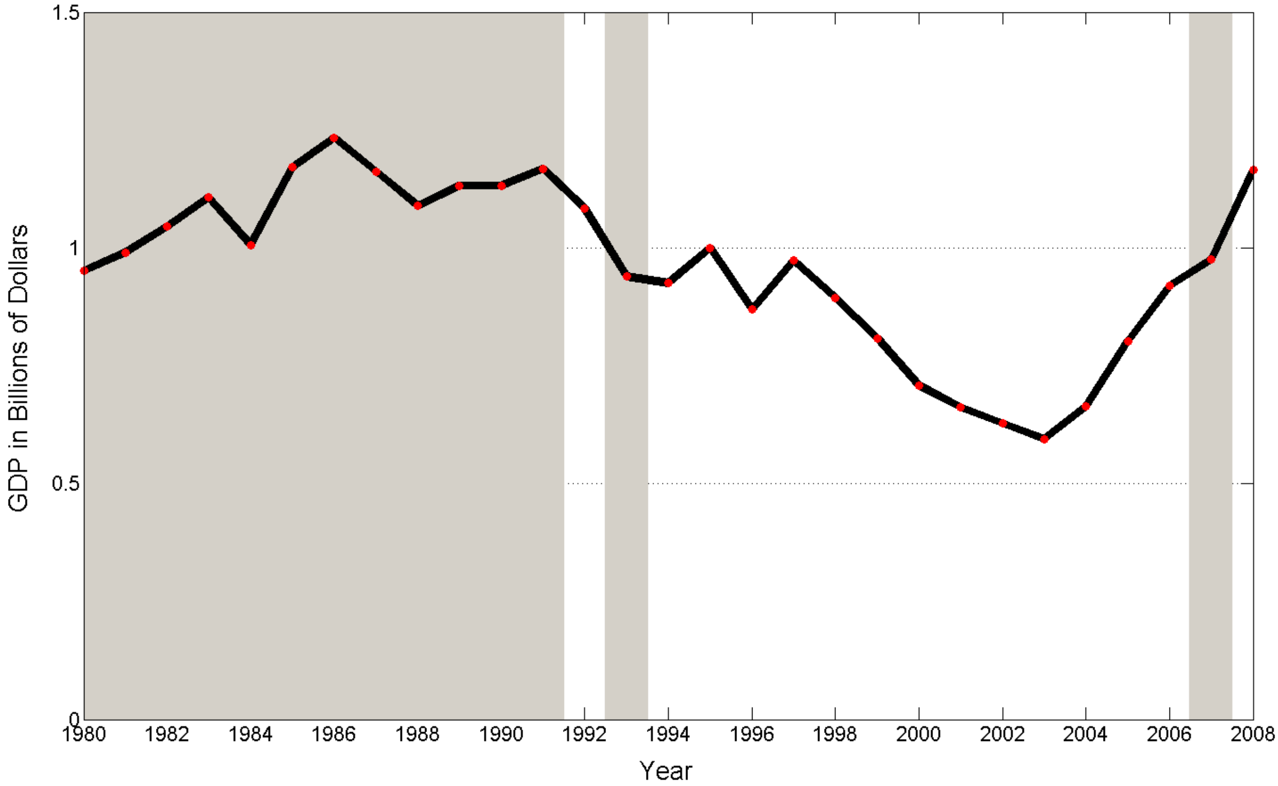

FIGURE 9: GDP OF BURUNDI IN THE PERIOD 1980-2009. THE GRAY BARS DENOTE YEARS SPENT AT PEACE. NOTE THE RELATIVE DECLINE OF GDP DURING CIVIL WAR.

Figure 9 shows that GDP declined in the periods Burundi spent at war in the last few decades (International Monetary Fund, 2011). Observations such as this, as well as anecdotal evidence, led us to introduce the parameter ε to simulate the devastation and disruption of civil war.

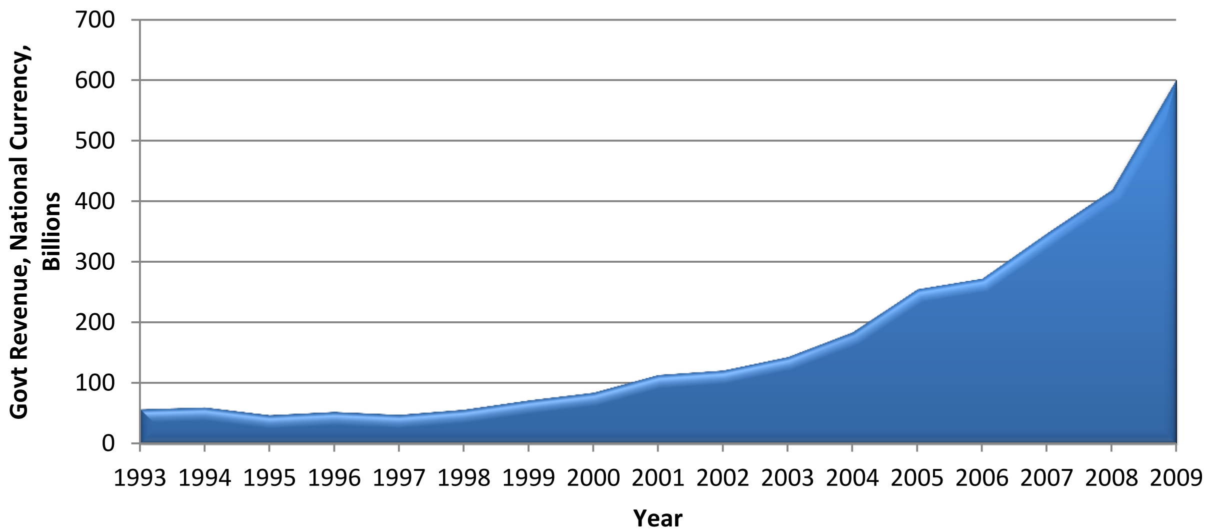

FIGURE 10: GOVERNMENT REVENUE FOR BURUNDI

Figure 10 shows government revenue figures for Burundi in a shorter period. This period was characterised by almost constant conflict, however major conflict[9] only occurred in 1998 and 2000-2002. This appears to have little effect on the upward trend of the revenues, but as we have seen in Figure 2, the state can often survive repeated minor wars, and actually increase its strength during these times. What is surprising however is that the graph barely flinches during times of (IMF definition) major conflict. This is possibly due to the difference in definitions of major conflict between the IMF and our model. Since the IMF defines war in terms of number of casualties, they do not capture the strength of participating factions. In effect, a one-time, one-way massacre would register as a civil war according to this definition.

Another very useful piece of data would have been government spending during the period. Unfortunately, due to the circumstances during times of civil conflict, governments of war-torn nations tended not to furnish the IMF with information on how they spent their money. Where this information does exist, it is usually fragmentary, and we cannot draw any clear picture from it[10]. However, IMF figures have been getting better over the recent years, and there is hope that within a decade sufficient data will be available to draw justified conclusions from.

Inequality data would also have been tremendously useful, but was unfortunately unavailable at this time.

5.5. Alternative Treatment of Lootable Resources

There were conceivably at least 2 other ways we could have approached the representation of lootable resources. Firstly, some fraction of them could have been shared with the state in peacetime like regular resources. However, this would have blurred the boundaries between the two types of resources, and added at least one extra parameter to the model. It was decided that this was an unnecessary complication.

The other possibility was to remove the peacetime dependence of political power on lootable resources (Equation 1). This is equivalent to saying that lootable resources are not harvested at all during peace. This is a plausible assertion, if we count things like robbery, theft and banditry as part of 'lootable' resources. These are, after all, common during civil wars (Collier, 2006). However, since our primary focus is on the effect of easily harvestable resources such as alluvial diamond deposits, it seemed sensible to leave the peacetime effects in the model. Factions possessing resources such as these are unlikely to stop profiting from them just because they have signed a ceasefire with the state[11].

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[9] Here major conflict is defined using the IMF intensity definition. Armed conflict resulting in 1000 or more combat deaths a year is listed as 'major'. In so many words, the IMF consider this to be civil war.

[10] As such, it has been omitted from this report. We investigated the spending of Liberia, Angola and Burundi, but barely 10 years' worth of good data exist, and usually in disjoint periods.

[11] Collier cites the amusing case of Sierra Leone, where the leader of a rebel group was given the post of Minister for Mining as part of the peace settlement. It is perhaps not too controversial to assume that his reasons for taking up the post were not entirely selfless.

5.6. A REPLACEMENT FOR ASABIYA?

The greatest advantage of Turchin's Meta-Ethnic Frontier theory (Turchin, Historical Dynamics: Why states rise and fall, 2003) as an explanation of political cycles is that it applies both within states as well as between states. Indeed, it offers a consistent explanation for the spontaneous rise of new states as well. Our model has nothing to say about the interaction between states, and so cannot displace asabiya on this count. However, we do offer a plausible alternative for within-state interactions using more measurable units. It should also be noted that our model and the asabiya-based theories are not mutually exclusive, and that some combination of the two may well provide a better explanation for political cycles.

6. CONCLUSIONS

Our model does appear to be broadly consistent with empirical data, and encompasses many of the behaviours that we expected. There is indeed a cyclic dynamic to factional strength, and there is scope for leader replacement. The outbreak of major wars are shown to be governed by many factors, but chief amongst these are the penalty for war, the disruption of regular resource production during war and the quantity and spread of lootable resources. The effect of each of these are pronounced and nonlinear, and it may be possible for a state to choose them in such a way as to minimize conflict.

7. FUTURE WORK

7.1. APPLICATION TO AFRICA

The model needs to be fitted to a specific case much more than has been during the course of this project. This was due to lack of time and limited access to necessary information. However, we have laid a useful mathematical groundwork, meaning that fitting the model should be quite easy once the required data becomes available.

7.2. ALTERNATIVE TREATMENT OF LOOTABLE RESOURCES AND WAR PENALTY

It would be interesting to see what effect the alternative interpretations of lootable resources discussed in section 5.5 would have on the model. Also, p_w could be turned into a costly punishment term to which all conforming factions contribute (Henrich, 2006).

7.3. STATISTICAL ANALYSIS

Much of the time in this project was spent in constructing the model, so there is still scope for further analysis of the model. The first task would be to continue the ANOVA analysis by calculating the relative effects of each parameter as a percentage. Next we would build on the parameter analysis in sections 4.2 to 4.4, especially considering the transition regions between one stable state and leader replacement.

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9. List of Tables

10. List of Equations

11. List of Figures

12. APPENDIX

12.1. MATLAB

The model was implemented using MATLAB, a mathematics oriented programming language produced by MathWorks (MathWorks). This was used extensively, and by implementing successive versions of the model and new ideas as they came up we were able to judge the merits of proposed changes very quickly. The statistical and plotting tools that MATLAB provide are also very useful, and allow for quick analysis and representation of data as it is produced. Finally, MATLAB can also be used for object-oriented programming (MathWorks, 2008), meaning that extending our model into an agent-based or spatially explicit model should be easier, should this be needed in future.

12.2. PARAMETER SCANS

These graphs were made by running the model for a range of parameters. They were used in investigating the effect of each parameter, and are still a useful visualisation of parameter effects.

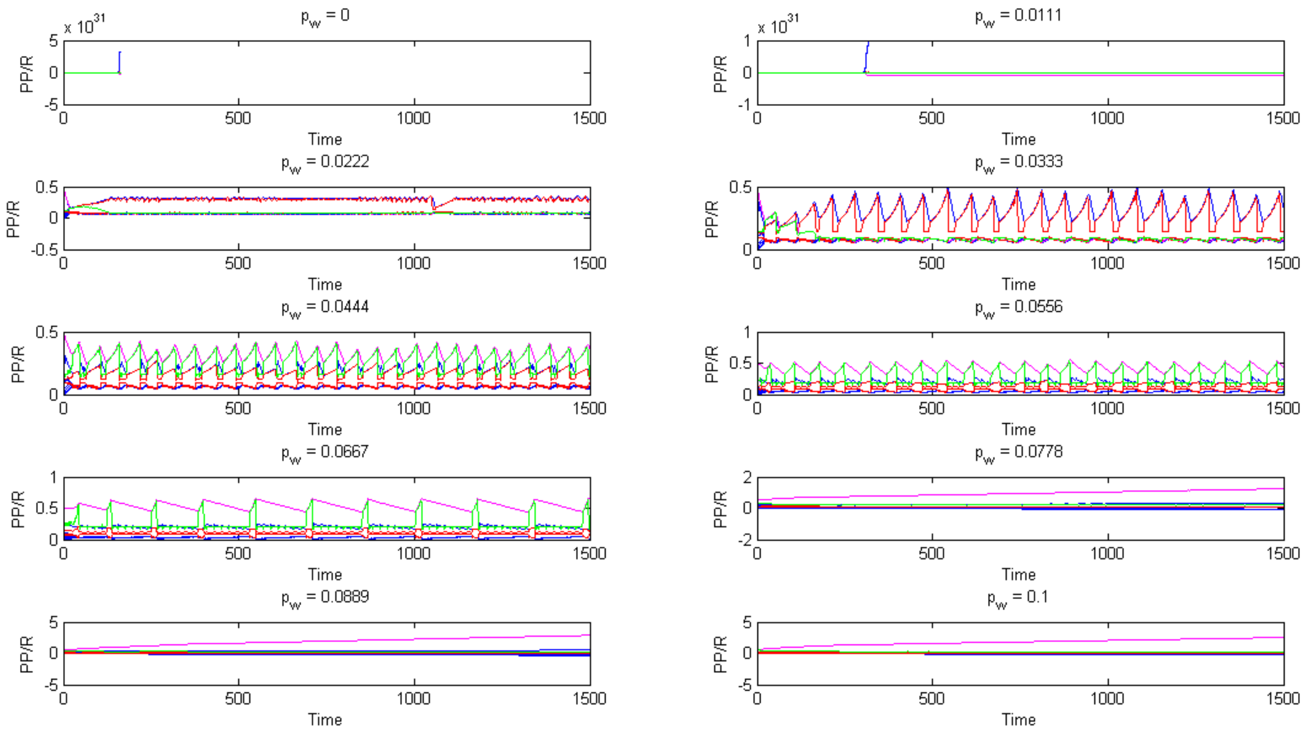

FIGURE 11: PARAMETER SCAN OF WAR PENALTY, P_W

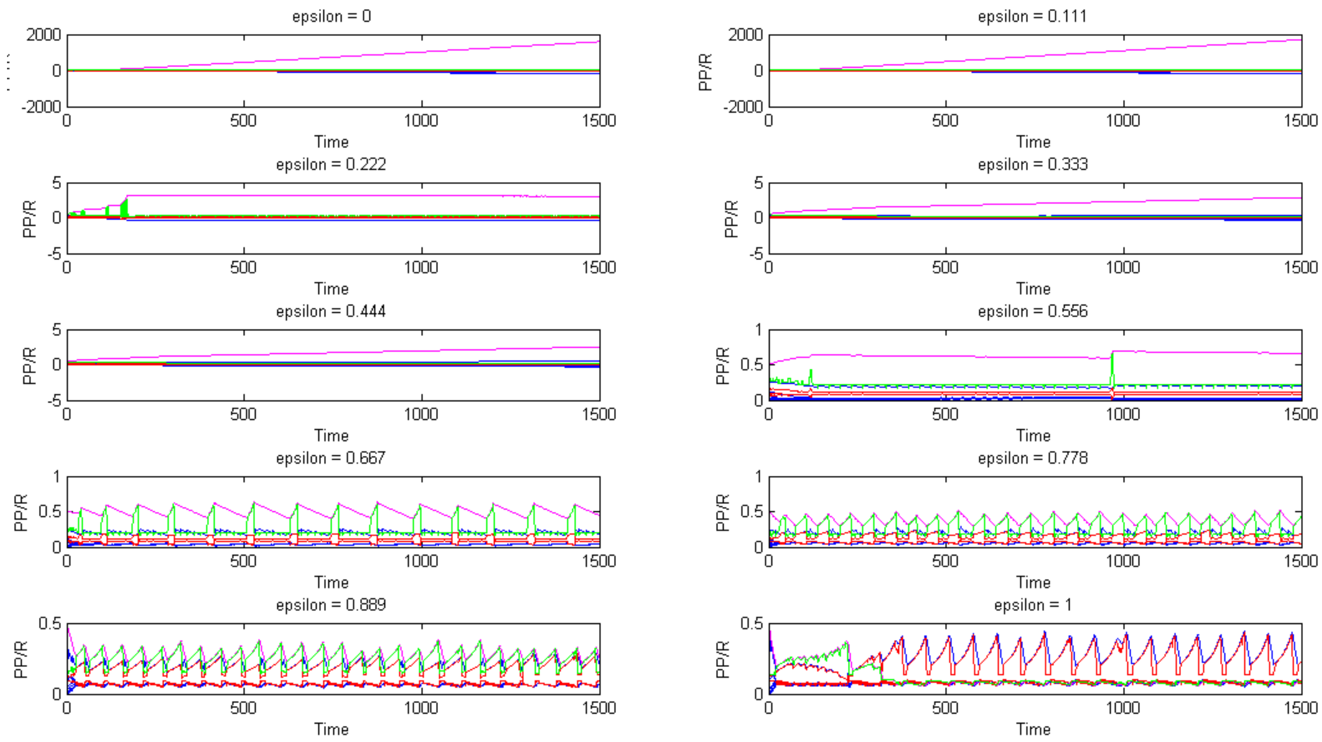

FIGURE 12: PARAMETER SCAN OF RELATIVE VALUE OF REGULAR RESOURCES IN WARTIME, ε

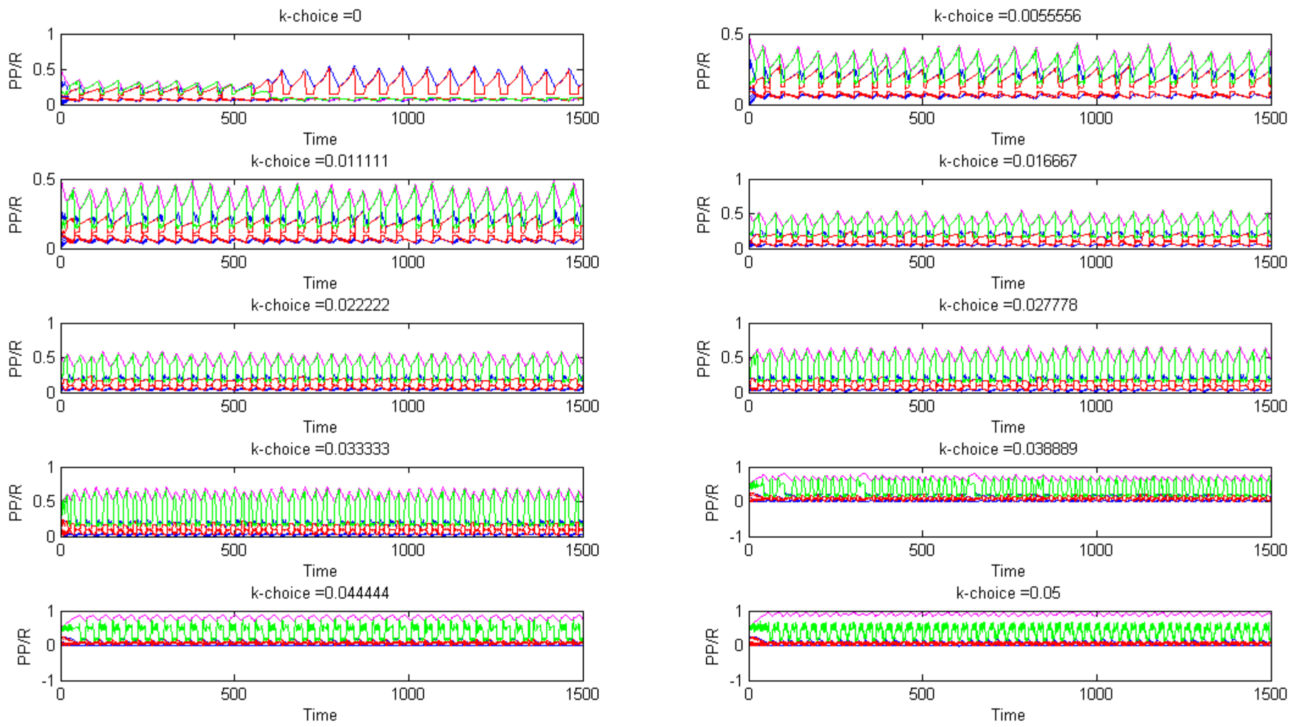

FIGURE 13: PARAMETER SCAN OF BIAS TO PEACE IN DECISION MAKING, K_{CHOICE}