The Pennsylvania State University

The Graduate School

Department of Political Science

THE SINEWS OF STRIFE: STATE INFRASTRUCTURE AND INTERSTATE CONFLICT, 1840 – 1993

A Thesis in

Political Science

by

Christopher Eric Housenick

© 2005 Christopher Eric Housenick

Submitted in Partial Fulfillment
of the Requirements
for the Degree of

Doctor of Philosophy

August 2005

The thesis of Christopher Eric Housenick was reviewed and approved* by the following:

Glenn Palmer
Associate Professor of Political Science
Thesis Advisor
Chair of Committee

D. Scott Bennett
Professor of Political Science

Douglas W. Lemke
Associate Professor of Political Science

William Bianco
Associate Professor of Political Science

Colin R. Flint
Associate Professor of Geography

Donna L. Bahry
Professor of Political Science
Head of the Department of Political Science

*Signatures are on file in the Graduate School

ABSTRACT

This dissertation examines and provides evidence for the research question: *How does infrastructure shape and influence international conflict?* Chapter One begins by establishing that infrastructure is *the internal network of a country that facilitates the conduct of various activities.* Overall, there are six broad categories of infrastructure (transportation, communication, electrical, political, medical and sanitation, and maritime). The research in this dissertation will better improve our understanding of international conflict initiation, increase our knowledge about war outcomes, deepen the research into the role of technology in international relations, and expand our understanding of national capabilities.

Chapter Two presents a theoretical foundation for the examination of infrastructure. State leaders have a variety of goals that they want to achieve, and some of these goals involve international conflict. In order to achieve their goals, states possess capabilities which shape their probability of successfully achieving their respective goals. The primary focus of previous research has been on how broad national capabilities (CINC scores and GDP in particular) affect the probability of successfully completing the state's goals. However, Morgan and Palmer (1997) argue that *technology* is another approach to the achievement of state goals. Infrastructure is a form of technology that influences the ability of a state and its leadership to achieve its goals.

When a state possesses better infrastructure, this allows the military apparatus of a state to move faster, be better supplied, and lose less strength within the borders of the state. With these potential benefits in mind, state leaders examine their infrastructure

relative to other states. If state leaders find that they possess an advantage in infrastructure over another state, they should be expected to pursue more bellicose and conflictual policies because their state will possess an advantage, thereby increasing the probability of success in the conflict, when holding everything else constant. With this theoretical foundation, I put forward six hypotheses regarding the outcome of interstate wars (either victory or defeat) and twelve hypotheses regarding the initiation of militarized interstate disputes.

Chapter Three presents the first cross-national data set for transportation and communication infrastructure in order to statistically test the hypotheses set forth in the Theory Chapter. Transportation infrastructure is the factor score of the number of railroads per square kilometer, the number of automobiles per square kilometer, and the number of air travel passenger kilometers per square kilometer. Communication infrastructure is a factor score of the number of telegraphs per person-kilometer and the number of telephones per person-kilometer. With this data, I then perform a number of tests to make a prima fascia case that this data is properly representing the states of the international system.

Chapter Four uses this new data set measuring transportation and communication infrastructure to test the six hypotheses concerning the outcome of interstate wars. I find that advantages in relative transportation infrastructure and relative communication infrastructure after World War One improve the probability of a state winning a particular war. I also find that three other indicators—democracy, development, and initiation—are all insignificant after controlling for transportation and communication infrastructure.

Chapter Five empirically examines the relationship between militarized interstate dispute initiation and transportation and communication infrastructure. This analysis finds that differences in infrastructure do in fact influence conflict initiation. Prior to World War One, transportation infrastructure was a dramatic influence over conflict initiation, have more than three times the effect of national capabilities during that era. In the contemporary era, communication infrastructure plays a significant role in shaping the initiation of militarized interstate disputes; however the statistical findings of this model contradict my theoretical expectations. In addition, I find that considerations of infrastructure are a generalizable finding across all the states of the international system; statistical test to see if infrastructure is limited to only Western states such as the United States and Europe are unsupported in this analysis.

Chapter Six brings this project to a close by summarizing the empirical findings of this entire dissertation. The second section of this chapter discusses the important data set extensions necessary for this project's future. Third, this chapter talks about the large number of potential research questions that could be addressed with the data and theory presented in this dissertation.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

In any research endeavor, there is always a host of individuals who are owed credit for their roles in moving a research project from an idea to reality, and there are four groups of people I need to thank for their involvement in this dissertation. The members of this project's committee are the first people I have to thank. Their individual and collective contributions to this research greatly enhanced the work here in many different ways. As the chair of this dissertation, Glenn Palmer's guidance for the last two years was invaluable in getting this project completed. Stepping into a leadership role for a project initially guided by someone else is challenging to say the least; I simply do not have words to express my gratitude to him for assuming the leadership role of this dissertation when Stuart Bremer was unable to continue forward. In addition, Glenn's perpetual need to be strongly convinced of the arguments within this work made the theories and discussions throughout this dissertation much stronger.

I also want to thank Scott Bennett for his guidance as this project progressed. His evaluations and recommendations for many of the statistical investigations presented here improved the robustness and level of sophistication of these analyses. While many of his individual suggestions appeared relatively minor, collectively they made a dramatic improvement to this dissertation. Doug Lemke provided this project with a boost of much-needed adrenalin when he joined this committee later in the project's evolution. Bringing his fresh opinions, ideas, and inspirations to this project in Fall 2004 gave this dissertation a swift kick that helped it progress much faster towards completion. Colin Flint also provided a much-needed geographer's point of view for this project. His assurances that a geographer understood and accepted the arguments within this political science dissertation provided an outside validity that made this work more generalizable. Finally, I have to thank Bill Bianco for his hands-off approach to this dissertation. By allowing me space and freedom of action, he enabled me to avoid many of the potential collective action problems that are often associated with dissertation committees containing more than the minimum number of members.

The second person I have to acknowledge in this project is the original chair of this project, Stuart Bremer. His original vision and guidance regarding the potential importance of this project got the ball rolling that eventually manifested itself as the research presented here. When he passed away in the Fall of 2002, there was a point where the future of this research seemed somewhat jeopardized. Through hard work and the support of everyone involved, his initial vision of this project has been achieved.

The third group of people I need to acknowledge is the faculty and graduate students of the Department of Political Science here at Penn State University. Portions of this dissertation have been presented at many international relations reading groups over the course of the past two and a half years. The ideas and suggestions they provided have improved several portions of this project, improving the overall presentation of the ideas and discussions contained within this dissertation. Likewise, when this research was presented to the wider faculty of Penn State, the suggestions they provided improved this dissertation by helping shape it to be accessible to a wider audience.

Finally, I have to thank my family for their support that made this endeavor possible. I have to thank my mother Carol and my brother Craig whose belief in me helped spur me on to finish this endeavor. Most importantly, I have to give special thanks to my loving wife Danielle. Her love and encouragement on a number of levels gave me the strength and opportunity to make this project possible. Her unconditional support at both the highest of highs and the lowest of lows gave me the stamina to finish this marathon. Without her efforts, sacrifice, and patience, none of this would have been accomplished.

Chapter 1

Infrastructure Introduced

Social scientists, historians, and political leaders all have advanced explanations as to why some phenomenon caused, influenced, shaped, or otherwise affected a particular conflict. A wide variety of potential explanations serve as mitigating factors surrounding international conflict, including such prominent examples as alliances, power, democracy, national capabilities, domestic politics, misperception, economic interdependence, and international organizations. Researchers have examined these variables regarding international conflict in order to alleviate the danger, violence, pain, suffering, and loss that occurs when violent international conflicts erupt and full-scale wars are fought between the states of the international system.

This dissertation follows this tradition of attempting to understand more about international conflict. However, the research presented here introduces a new area of examination into the study of international conflict and war: infrastructure. This project examines and provides evidence for the research question: *How does infrastructure shape and influence international conflict?*

The research presented in these pages provides several important contributions. The theoretical discussion contained in Chapter Two elucidates the reasoning why infrastructure influences international conflict. In particular, the theory explains how infrastructure influences the outcomes of wars and the initiation of militarized interstate disputes. Chapter Three provides the first quantitative data set of infrastructure available for international relations that covers a wide variety of indicators over a long time frame (1840 – 1993). Chapter Four empirically examines the relationship between infrastructure and war outcomes, finding some very important results. More specifically, the findings indicate that infrastructure is an important determinant of who wins and loses wars, and that two other important indicators of war outcomes—democracy and initiation—have no statistically significant effect after controlling for infrastructure. Chapter Five tests the relationship between infrastructure and the beginning of international conflict, and finds that differences in infrastructure do influence who initiates or is the target of militarized interstate disputes.

This chapter lays the foundations for an in-depth examination of infrastructure and its role in international conflict. The first section of this chapter presents a definition of infrastructure. In order to research and examine a particular phenomenon effectively, it is necessary to define the concept under study clearly. The second section of this chapter categorizes and discusses the multiple forms of infrastructure that exist within states. Infrastructure is not homogenous; it contains many subdivisions and subcomponents that must be identified and categorized in order to examine and discuss this phenomenon meaningfully. The third section of this chapter examines and identifies the initial motivations of this research, discussing what created the spark that resulted in this project. The fourth section of this chapter elucidates how understanding the role of infrastructure compliments previous research in international relations. For any research endeavor, it is important that the research expands and deepens people's understanding of international relations, and the work presented here is no exception. Finally, the concluding section of this chapter briefly outlines the rest of this dissertation, providing a framework for the research which follows.

Infrastructure Defined

In order to study this concept of infrastructure, it is necessary to first understand what infrastructure is and what it is not. With that in mind, one of the most difficult yet important things to do is to arrive at a simple, parsimonious definition of infrastructure because there are a large number of different definitions for this concept. Several typical definitions for infrastructure appear in Table 1.1 below.

[Insert Table 1.1 about here.]

This brief summary depicts one of the problems regarding the study of infrastructure. Finding a single, generalizable definition of infrastructure is very difficult. Some definitions of infrastructure are too narrow, focusing and limiting the realm of infrastructure only on economic considerations, such as those definitions presented by Pearce, Bishop, and Diamond and Spence. Other definitions are so broad that they are vague, such as the one advanced by Webley and found on dictionary.com.

With these many varied definitions for the same phenomena, it was necessary to create a more simplified, universal definition for infrastructure that captures as many of the major themes contained in these previous definitions as possible. For this research, I define infrastructure as: *the internal network of a country that facilitates the conduct of various activities.*

This definition touches on three important commonalities between the above listed definitions of infrastructure. First, it identifies that infrastructure is comprised of networks. There are a host of various systems throughout countries that allow them to function and operate on a day-to-day basis. All the aforementioned definitions of infrastructure mention or refer to some form of system.

Second, this definition addresses the idea that infrastructure plays a role in facilitation. Infrastructure provides opportunities and promotes activities within states. Infrastructure systems attempt to make a very broad range of actions easier and less costly for the inhabitants, businesses, and the government of a particular state. For instance, businesses within a state could emerge and grow, but their vitality and profitability will be greatly increased through the presence and expansion of infrastructure in their vicinities (Shah 1992).

Third, this definition captures the idea that infrastructure influences activities, making its citizens, inhabitants, firms, and government able to perform certain actions that they may otherwise not have been able to perform. Most of the definitions that include some form of economic component and activity are correct; infrastructure can influence economic actions. However, infrastructure is not limited to only that one area of action. For instance, infrastructure extends to social activities (such as educational and governmental systems), healthcare activities (such as hospitals and clinics throughout the state), and maritime activities (such as ports and canal systems).

It is important to highlight that infrastructure only facilitates a number of activities, and is not perfectly associated nor a direct substitute for several other concepts that are commonly examined as state characteristics. There is a common conception that infrastructure is near-perfect representation for a rather wide variety of other phenomena, including such things as development (Hegre 2000), state wealth (Greenwald 1994), democracy (Diamond 1992), and social mobility (Roberts 1989). While it is the case that infrastructure does promote and facilitate these ideas of development, state wealth, democracy, and social mobility, it is not the case that infrastructure in its many forms is perfectly associated with all of them. Throughout this dissertation, I will provide evidence that infrastructure is a separate, distinct consideration from many other concepts used in international relations, political science, and a variety of other disciplines.

There are two additional elements that previous research efforts have attempted to integrate into the definition of infrastructure.[1] The first element that has been attempted is that infrastructure is a public good. The second element that previous research has attempted to incorporate into definitions of infrastructure is that infrastructure is immobile. I will discuss why these two elements are not included within this general definition of infrastructure.

Public goods are one potential element that some researchers attempt to include into definitions of infrastructure. Their argument is that states build infrastructures in order to provide greater public goods for their citizens, making it possible for everyone in a society to move or communicate within the state (Rietveld and Bruinsma 1998, 18-19). One example of a public infrastructure is non-toll roads. These are constructed in order to speed transportation between places within the state.

---

[1] Rietveld and Bruinsma identify these elements that other researchers have attempted to include in a definition of infrastructure. Their discussion was rather brief, so I expand on their work here.

However, there are numerous examples where infrastructure is not freely utilizable, making it a private good. Air and rail travel in many states is a private good; airlines and railroads sell tickets to passengers, excluding those who cannot pay from utilizing their services. Electricity is also a private good, being excluded from those unable or unwilling to pay for its provision. While some roads are public goods, there are large numbers of private toll roads in many countries throughout the world and in New Jersey. Telegraph and telephone communication systems are all private goods, offered for a fee from corporations. In summary, while states do provide some infrastructure as a public good, this is not a universal quality for all infrastructure systems and therefore not included in definitions of infrastructure.

Immobility is a second element that previous research has attempted to integrate into definitions of infrastructure. Immobility addresses the idea that infrastructure is often tied to a fixed location once it has been constructed (Rietveld and Bruinsma 1998, 18-19). After constructing a roadway, tunnel, airport, or canal, it is impossible to move these forms of infrastructure once they are built.

While this property might be true for some forms of infrastructure systems, such as the aforementioned roads, railroads, and airports, there are many other examples of infrastructure that can be moved. Contemporary communication systems are one example of potentially mobile infrastructure networks. Computer network servers can be relocated and repositioned, telephone calling centers can be easily re-routed in times of electronic failure, and cellular telephone networks and towers are relatively inexpensive to construct or remove as the situation dictates. Therefore, since this characteristic is not universal for all definitions of infrastructure, it is also excluded from my definition.

In conclusion, infrastructure is defined as the internal network of a country that facilitates the conduct of various activities. Infrastructure is not defined in terms of public versus private goods, nor by immobility. While this definition is parsimonious, it also leaves itself open to include a great number of potential systems that can serve as the infrastructure of a state. Identifying and categorizing these differing types of infrastructure systems is next.

Types of Infrastructure

Part of the difficulty in defining infrastructure as a concept stems from the problem that infrastructure consists of many different subdivisions and categories. These sorts of systems are not as simple and relatively homogeneous of a concept as military personnel, but rather a very diverse and often confused term.

Several different categorizations attempt to sort out the diverse components that comprise infrastructure. Hirshman identifies transportation systems and power (electrical) infrastructure as the two (and only two) areas of infrastructure (1958). Biehl and his coauthors identify twelve areas of infrastructure: transportation, communications, energy supply, water, environmental, education, health, special urban (local), sports and tourist facilities, social, cultural facilities, and natural endowment (1986). Bannock and his coauthors identify six areas of infrastructure: roads, airports, sewage and water systems, railways, telephones, and other public utilities (1992). Writing alone in another venue, Biehl lists seven forms of infrastructure: roads, railways, waterways, airports, seaports, pipelines, and telecommunications (1993).

With such wide varieties in the categories of infrastructure, it is necessary to delimit and define the most commonly-associated categories available. Looking across these four lists, it would appear that there are six broad, distinct categories of infrastructure. All six categories are briefly presented in the section that follows, however this dissertation only examines two of these categories in detail—transportation infrastructure and communication infrastructure.

Transportation Infrastructure

Transportation infrastructure consists of the systems within a state that allows it to move people or physical things across geographic distances. Transportation infrastructure consists of several components: roadways, automobiles, railroads, and airports all help to form the transportation systems of a particular state.[2]

Overall, the study of transportation infrastructure is probably the most complete and coherent of all six categories of infrastructure presented here. A specialty discipline of geography (conveniently called transportation geography) specifically deals with the influence and effects of transportation systems and their ability to produce and promote basic human survival (Pirie 1993) and economic growth (Justmann 1995; Linneker and Spence 1996; Morrison and Schwartz 1996). In addition, this variant on geography also examines the negative effects often associated with transportation systems, such as pollution and urban sprawl (Farrington and Ryder 1993; Black 1999; Davis 1999).

---

[2] Some may consider boats or other naval transportation assets an element of transportation systems. Because they rely on water sources and other maritime assets to function, they are discussed in greater detail as part of maritime infrastructure in a later section.

Communication Infrastructure

Communication infrastructure encompasses systems that transmit ideas and information electronically across distances. Telegraphs, telephones, cellular networks, and the Internet all comprise the communication infrastructure of a particular state.

Introducing and examining the role of communication infrastructure has been spurred on by recent technological developments. While communication infrastructure has existed for several hundred years, recent developments have driven it to the forefront of discussion and examination. The invention and explosive growth of cellular telephone networks and the Internet provides researchers with a host of potential research questions. Since there has been this recent emphasis on communications infrastructure, it should be included as a prominent point of study in this analysis.

Electrical Infrastructure

Electrical infrastructure has played a significant role in everyday life since the harnessing of electricity in order to power lights, radios, refrigerators, manufacturing facilities, and an incredible variety of other machinery. Because most societies rely on electricity to function, this appears to be an important element of state infrastructure to capture and measure.

This form of infrastructure has been accounted for in measures of national capabilities for more than twenty-five years. The Correlates of War National Capabilities Data Set has included a measure called Primary Energy Consumption ever since it was introduced in the 1970s (Singer, Bremer, and Stuckey 1977). The Primary Energy

Consumption data set serves as a proxy for the electrical infrastructure of a state. A state with a well-developed and well-built electrical infrastructure system should be able to produce, distribute, and therefore consume a much larger quantity of energy than a state with a poorly-designed, poorly managed and not maintained electrical infrastructure system. Therefore, electrical infrastructure has been integrated into previous research efforts and will not need to be addressed further in this research project.

Political Infrastructure

Most lists of infrastructure include references to educational systems, the presence (or absence) of effective government, social networks, and cultural networks. These are only a few examples of political infrastructure (Biehl et al. 1986).

I do not examine the role of political infrastructure because there are other research programs within political science that examine the effect of government in controlling and governing their populations and territories. There is a very strong parallel between the concepts and ideas mentioned above as political infrastructure and the political capacity literature within international relations. Organski and Kugler define political capacity as: "…the capacity of the political system to carry out the tasks imposed upon it by its own political elite, by other important national actors, or by the pressures of the international environment" (1980, 72). Jackman looks at the durability of political institutions in representing political capacity (1993). Since a number of authors have examined components of political capacity in previous research, I choose not to include this realm of infrastructure in the project I present here.

Medical and Sanitation Infrastructure

Medical and sanitation infrastructure are the systems of states that allow them to enhance the physical quality of life for their citizens, making them live healthier and longer lives. This type of infrastructure is comprised of such systems as doctors, hospitals, clinics, clean water access, and sewage removal systems (Biehl et al. 1986). There is not a universal standard for identifying and measuring medical and sanitation infrastructure. Therefore, this category of infrastructure should be left for a future research project and will not be considered in this discussion.

Several standards exist for measuring the medical infrastructure of a particular state. The number of hospitals, the number of clinics, the prevalence or absence of curable or preventable diseases, and the number of doctors are all potential indicators of the medical infrastructure of states in the international system. At this time, there is no consensus as to what constitutes an appropriate measure for the medical infrastructure of a state; therefore this element of infrastructure is left for future research.

Similar difficulties arise when considering sanitation infrastructure. Sanitation infrastructure can be measured by the presence or absence of sewage systems, the capacity of sewage systems, measuring levels of diseases that are associated with poor sewage conditions (such as malaria), or measuring levels of contaminants could serve to measure the sanitation infrastructure of a particular state in a given year. However, there is no general consensus as to what the most appropriate indicator of sanitation infrastructure would be; therefore it is left for future research.

Maritime Infrastructure

The sixth and final form of infrastructure is maritime infrastructure. This form of infrastructure concerns the rivers, lakes, oceans, canals, and coastlines of a particular state. Since long before Thucydides, humans have utilized water in order to survive, exist, and move throughout the world.

Generally speaking, maritime infrastructure is a relatively constant feature of a state. While it is possible to alter some maritime assets, such as dredging rivers to make them deeper, or to construct canals, the vast majority of maritime infrastructure is a constant and cannot be altered. A landlocked country like Afghanistan will be landlocked, and no amount of construction can change that situation. Other forms of infrastructure, such as transportation infrastructure, can be constructed (and destroyed) much more readily than maritime infrastructure. Railroad tracks can be laid down, roads can be built of dirt, concrete, or asphalt, and new airports can be constructed.

Maritime infrastructure is excluded from this analysis due to codification difficulties. In some instances, maritime infrastructure can be a powerful asset, improving the situation in favor of a particular actor and in other circumstances those same rivers and lakes can act as a hindrance and make a particular situation more difficult. An example of this is the invasion of Russia by Napoleon in 1812. The Lower Niemen River paralleled Napoleon's avenue into Russia, making it a valuable supply line for his troops. However, the Dnieper River, which ran perpendicular to his axis of advance, served as a large hindrance (Cate 1985, 122-123). It is not altogether clear how to codify maritime infrastructure so that a particular river is represented as an important asset in one circumstance and that same river becomes a point of potential difficulty or liability in another situation, therefore I choose not to focus on maritime infrastructure.

Motivations

An important question remaining to consider is why should this particular research program be undertaken? Of all the potential avenues of research, why choose to examine infrastructure over other possibilities?

The motivation for this research began after a broad consideration of the number of measurable phenomena available to international relations researchers for all the states in the international system. On one hand, the UN recognizes 191 states in the international system in 2005. With this many member states, this represents a great deal of heterogeneity in the world. On the other hand, however, there are not many data sets available that examine all the states of the international system. With so much diversity, there has to be more ways to differentiate between the states of the international system than current research suggests. The next logical question to ask is what is missing from this picture of international relations research?

The temptation may arise to run out and collect vast quantities of data. However, following a purely inductive approach to formulating a research agenda can leave researchers with vast quantities of data and no reasoning behind why that data may be important, interesting, or even relevant (King, Keohane and Verba 1994). In order to conduct more appropriate social research, there needs to be some justification behind data collection efforts. With this in mind, the question becomes what is an important element of states to measure that is theoretically driven and appealing to a wide audience. With a theoretical justification driving research, then the research has some logic and validation behind its undertaking. Being important to a larger audience would also contribute to the importance of this research. If the study presented here has applications beyond this immediate project, then the research would appear more relevant and important. Infrastructure is a theoretically-driven phenomenon that appeals to a wide audience and possesses the theoretical foundation for research.

Recent events in Iraq made infrastructure a prominent point of discussion in many venues. Three stories in particular illustrate these important discussions of infrastructure regarding Iraq and are presented in the paragraphs that follow.

The first story of infrastructure was during the First Persian Gulf War of 1991. During the month-long air campaign of January and February of 1991, it was common viewing on the nightly news to watch the destruction of various forms of infrastructure by coalition warplanes. Bridges, railways, airports, electrical plants, dams, and telephone exchanges often were shown being destroyed by an air strike. Infrastructure was a primary target of coalition forces, making it an important consideration of that war as a military target.

The second story of infrastructure involving Iraq occurred during late 2002 and early 2003 during the pre-war planning and positioning phase of the 2003 Iraq war. The initial US plan wanted an armored division to invade northern Iraq from southeastern Turkey. In order to do this, it would have been necessary to unload and transport tanks, armored personnel carriers, trucks, and maintenance vehicles almost 800 miles from the docks to the Iraqi border in order to attack from both the Turkish and the Kuwaiti borders. However, after the Turkish government was unable to secure parliamentary support for this plan in adequate time, the US altered its military strategy and only attacked Iraq from the south. Again, infrastructure played a significant role in this story. Because the US could not secure adequate, timely use of Turkish infrastructure in order to position their military forces, it became necessary to alter their overall military strategy and plans against Iraq.

The final story of infrastructure and Iraq came in the immediate aftermath of the war, during the preliminary rebuilding phases. Defense Secretary Donald Rumsfeld was speaking at the National Press Club after the war in Iraq. During his speech the concept of infrastructure arose when he said:

> I don't think people really fully understand how devastating that regime was to the infrastructure of the country—how fragile the electric system is, how poorly the water is being managed, and the extent to which the people are being denied.

Again, infrastructure was a prominent consideration. In this case, however, infrastructure was a problem that had to be remedied in the aftermath of that war.

These three stories of infrastructure attracted a great amount of attention and began moving this project forward. It appeared that infrastructure was a significant consideration when dealing with Iraq in a variety of ways. Infrastructure was the target of coalitions, the shaper of military plans, and a difficulty in reconstruction efforts.

The next logical question was whether or not these observations of events surrounding Iraq were evident in other cases of international conflict. Broad historical inquiries into the presence and importance of infrastructure during times of international war produced a number of cases where infrastructure played an important, prominent role in conflict behavior. For a large number of wars across a long time frame, states have actively targeted and destroyed components of one another's infrastructure systems. During the latter stages of the war in Vietnam, President Nixon ordered the mining of Haiphong Harbor in 1972 in order to deny North Vietnam its use, eliminating its effectiveness as infrastructure (Karnow 1983, 658 – 661). During the Six Day War of 1967, the Israeli army attacked along five avenues through the Sinai Peninsula—the five railway lines that crossed this region. One of the major battles of this war surrounded the strategic crossroads of Abu Agheila in the Sinai Peninsula (Bowen 2003).

This idea that infrastructure is an important consideration during times of conflict or even to international relations more broadly is not limited to the Twentieth Century. The roots of infrastructure and its role on international relations can be traced back to antiquity. During the time of Alexander the Great, infrastructure played a vital role in shaping his conquests. During his childhood, "Alexander seems to have displayed a precocious interest in the length of Persian roads…" (Engels 1978, 2). During his legendary marches and conquests across Asia: "each of the routes followed by the Macedonians is the result of a conscious decision by Alexander to best fulfill his army's strategic and logistic needs" (Engels 1978, 4). A very similar image emerges when considering the Roman Empire. One author writes: "Travel and communications are dynamics which were central to the Roman Empire. Its sheer size and diversity demanded that there was an efficient system of communication in order for government to take place" (Adams 2001, 1). A major contributing factor to maintaining that empire was the extensive road system, thereby illustrating the relative importance of infrastructure in some form almost back to the time of Thucydides.

While there are a large number of individual cases where infrastructure plays a vital and important role in international conflict and war, there are no broad empirical examinations of infrastructure contained within the literature on international conflict. This omission leads to two general problems. The first problem is that without statistical testing, it is difficult to show whether or not infrastructure is a generalizable phenomenon influencing international conflict across a wide range of cases and circumstances. As a broad field of study, international relations research contains many single, specific cases where a particular phenomenon seems to be in effect. However, many phenomena often do not operate when examining all of a certain phenomena. Without a broad-based statistical approach, it is not possible to see if this is a generalizable influence across a large number of cases and across a long time frame.

The second problem created by not empirically examining infrastructure is that it is difficult to make comparisons regarding the relative magnitude of infrastructure's role in international conflict. One of the important contributions of statistical research is that these techniques can examine the relative strengths of the various measured explanations included within the models. For instance, when examining the onset of conflict it is possible to identify what independent variable has the greatest relative effect on the probability of a dispute occurring in a particular year when compared to a host of other explanations. Bremer identifies contiguity, enduring rivalries, national capabilities, and regime types as the strongest, most robust statistical findings while alliances and major power status are less important determinants of when violent international conflicts arise (2000, 24-26). These sorts of direct comparisons are far easier to make and argue through statistical techniques. Therefore, examining infrastructure through statistical techniques would give us a basis to examine the effect of infrastructure when compared to other explanations of international conflict, such as democracy, national capabilities, contiguity, and a host of other theoretically interesting concepts.

Infrastructure and Understanding International Relations

This research into the role of infrastructure on interstate conflict can expand our understanding of international conflict in several ways. It will expand our understanding of conflict onset and initiation and the outcomes (winning versus losing) of wars. Delving into infrastructure will also touch on questions surrounding the role of technology on conflict, the effects of geography in international relations, expand the realm and understanding of national capabilities, and also address questions of importance to policy makers in the United States Department of Defense. I will discuss each of these areas of understanding in turn.

Expanding our understanding of the relationship between dispute onset and initiation is the first area of international relations where this research will make a contribution to this literature. Current models of conflict onset often have difficulties in predicting the onset of international conflict. Expanding our understanding of this phenomenon is important because disputes are far more prevalent than wars in international relations.

Examining the role of infrastructure will expand our understanding of war outcomes. Recent studies on who wins and loses wars generally refine current existing explanations. For instance, Reiter and Stam examine curvilinear and interactive relationships between democracy, initiation, and winning wars (1998). Infrastructure's presence as a significant statistical relationship or the relative magnitude of this hypothesized relationship has not been included in these forms of analysis before, even though several historical works focus on the importance of these systems as mentioned above.

Exploring the role of infrastructure will also broaden our understanding of how technology impacts international conflict. Previous studies on this topic have covered two broad areas—nuclear weapons and military quality. Regarding nuclear weapons, Fearon found that possession of these forms of weapons by the defender made extended immediate deterrence for a protégé state more successful (1994, p.255-256). Geller found that disputes between states both possessing nuclear weapons often led to violence, but almost never escalated to war (as defined by the Correlates of War Project), while disputes between one nuclear and one non-nuclear state were just as likely to escalate as two non-nuclear disputing states, and more likely to escalate than disputes between two nuclear adversaries (1990, 306-308). When examining the effect of military quality, a state that possesses an advantage in military expenditures per soldier has been shown to shorten the length of interstate wars (Bennett and Stam 1996) and increase the probability of winning a war once it has commenced (Reiter and Stam 1998).

While these two areas of technological distinctions between adversaries are important, there are many more potential areas of technological distinction and difference between the states of the international system than simply nuclear weapons and military expenditures per capita.[3] For instance, the presence of precision guided munitions, stealth technology, or personal body armor by one side of a conflict can provide a marked advantage over their adversary under the right conditions. A state armed with precision guided weapons can attack their opponent more efficiently because their weapons will fall more accurately on their designated targets, while a state with conventionally guided weapons will have to use more of them to damage and destroy their targets because of the larger margins of error involved in conventionally guided weapons. If one state possesses and utilizes stealth aircraft, then that state can attack its adversary with near impunity, because the state without stealthy aircraft will not be able to target and destroy its attacker. If the soldiers of one state are equipped with personal body armor, then that state will suffer fewer casualties and fatalities, thereby increasing their ability to win their conflicts and wars.

Infrastructure is another form of technological distinction between two states that can shape a host of conflict behavior, including conflict onset, initiation, and outcomes. Like nuclear weapons, military quality, stealth technology, precision guided munitions, or personal body armor, differences in infrastructure provides fungible benefits on the battlefields of yesterday, today, and tomorrow's wars, and can provide advantages or disadvantages in conflicts and wars that state could exploit.

---

[3] This line of argument parallels one regarding "leading sectors" technologies set forth by Modelski and Thompson (1995). They argue that one element that helps maintain hegemony is that the hegemonic state often possesses certain technological advantages over all other states of the international system. What I am arguing here is that these sorts of technological advantages are not limited to the hegemon, but can exist through all the states of the international system.

Examining infrastructure would also improve our understanding of the relationship between geography and international conflict. In current studies of interstate conflict, geography is often captured using the four techniques listed below:

1. A dichotomous variable indicating whether or not the two states in a dyad are contiguous with each other by some standard, ranging from sharing a common border to separate by no more than four hundred miles.
2. A continuous variable measuring the curvilinear distance from the state capitals to each other (or measured from the closest relevant point in a particular state).
3. A continuous variable capturing the relative density of the terrain within a particular state during wartime (Dupuy 1979, 1983; Dupuy and Dupuy 1986).
4. A categorical variable capturing the relative ease or difficulty associated with crossing a particular border between two states (Starr 2003).

Several problems are associated with each of these previous efforts of geographic measurement. Studying contiguity through dichotomous variables almost functions as a constant; there is so little variation in contiguity measures, it is a wonder that statistical models can make this distinction. The measures the terrain within states are not available for all the states of the international system, being utilized almost exclusively for smaller-N studies of war duration and outcomes (Bennett and Stam 1996; Reiter and Stam 1998) while the data set on border passable is restricted to only a few select states at this time.[4]

Examining infrastructure would introduce more geographic components into our understanding of international relations. Rather than relying on only dichotomous

---

[4] The article containing this data set indicates that this data set should be expanded to cover all contiguous states in the international system.

measures of contiguity, straight-line measures of distance, and the occasional measure of terrain in smaller-N studies, measuring infrastructure would begin to illuminate how states can alter and potentially overcome their physical geography, thereby expanding our understanding of how geography and international relations interact.

Incorporating infrastructure into the international relations literature would also increase our understanding of national capabilities. Current studies of international relations focus on one of two measures: 1) The Composite Indicator of National Capabilities (CINC); and 2) Gross Domestic Product. CINC scores are calculated based on six dimensions of national capabilities: military personnel, military expenditures, primary energy consumption, iron and steel consumption, total population, and urban population. These six components while important and theoretically important, are not the only dimensions of state capabilities that could be of importance.

Measuring and testing the effects of infrastructure would expand this knowledge base regarding national capabilities. Incorporating infrastructure into the dialogue and discussions of state elements that they can potentially control and utilize during times of peace, conflict, and war would give states a greater menu of potential options, more closely approximating the numerous choices and opportunities that states possess in peacetime and war.

This dissertation would also provide important evidence and guidance to policy-makers in the United States Department of Defense. A very prominent program in the Department of Defense is the program of strategic mobility. Former Chairman of the Joint Chiefs of Staff General John Shalikashvili is quoted as saying that: "The ability to move forces and equipment to the right place at the right time has always been a crucial factor in the success of military operations" (Phelps 1996). An indicator of its relative importance to current military planners is the amount of money spent on strategic mobility efforts. A Congressional report writes that funding for these programs are: "a top priority: the Administration plans to spend nearly $20 billion (in current dollars) from 1998 to 2002" (Congressional Budget Office 1997). There are two potential issues stemming from these assertions. First, this idea that strategic mobility promotes success in international conflict is not empirically tested by an outside, independent body. There does not appear to be an outside review of their findings that support the expenditure of billions of dollars annually on these projects. Because this dissertation will empirically examine the relationship between infrastructure and war outcomes, this dissertation can provide a rigorous, independent examination of this policy's merits.

The second problem associated with the Department of Defense policy is that there are no comparisons made with other explanations for why the United States (or any other state for that matter) would win a particular war. For instance, most scholars and people would argue that the most important factor in winning a war would be the relative number of troops on the ground. Simply put, having a predominance of troops over an adversary would seem to be a relatively strong indicator of military success. There are no comparisons made in their assertions about how much does a well-developed infrastructure system promote conflict and war victory when compared to something like the number of military personnel on the ground? If the relative importance of infrastructure was rather modest, then it would appear that the five billion dollars would be better spent on recruitment and retention of personnel than on infrastructure. This dissertation will independently evaluate these sorts of questions.

Project Overview

With the foundations set for this project, it is now important to outline how the rest of this research will progress. Chapter Two will lay out the theoretical foundations of how infrastructure shapes and influences international conflict. The general logic of the theory lies in technological differences between states. States have foreign policy goals that they want to achieve. If a state's leader perceives that they possess a technological advantage over another state, then we should expect to see more bellicose policies. When it comes to winning and losing wars, those technical advantages can mean the difference between life and death for the state and its citizens. In the decision to initiate disputes, infrastructure provides opportunities to gain advantages over a potential adversary, giving a state with a better infrastructure system the opportunity to initiate a dispute with another state.

In order to provide evidence for the hypotheses presented in Chapter Two, it was necessary to create a data set that can empirically test these assertions. Chapter Three presents this data set—the National Infrastructure Data Set. This data set covers the years 1840 until 1993 and examines all states identified in the international system by the Correlates of War Project. This data set creates two indicators—transportation infrastructure and communication infrastructure—out of five raw indicators (railroads, automobiles, air travel, telegraphs, and telephones). With these two indicators in place, this chapter then performs some initial tests of these measures, comparing them across a number of cases of international conflict.

Chapter Four will present the empirical evidence for how infrastructure influences the outcome, either in glorious victory or crushing defeat, of interstate wars. After replicating an examination of war outcomes by Reiter and Stam, I find that infrastructure is an important element in determining what state wins and loses a particular war. In addition, I find that their two variables of interest—democracy and initiation—are no longer statistically significant indicators of war outcomes after controlling for infrastructure.

Chapter Five will present the empirical evidence regarding infrastructure and militarized interstate dispute initiation. Findings in Chapter Four indicate that initiating states often possess infrastructural advantages over their adversaries. Chapter five directly tests these relationships, finding that differences in infrastructure can promote dispute onset between states.

Chapter Six will be the conclusion of this project. This chapter will summarize the findings and empirical evidence of the previous two empirical chapters. Then the discussion will move to examining how the data and discussions presented here can be utilized in future research.

Chapter One Tables

Table 1.1: Previous Definitions of Infrastructure

Definition	**Source**
Those structural elements of an economy which facilitate the flow of goods and services between buyers and sellers	Pearce 1992, 206
The essential elements of a structure	Levy 1996, vii
The network of public works which are basic to the economic and social life of any nation-state	Webley 1985, 1
The economic arteries and veins…that enable people, goods, commodities, water, energy, and information to move about efficiently	Bishop 2000,124
An underlying base for a system or organization	Dictionary.com
The collective and integrative basis for economic activity	Diamond and Spence 1989, 14
Provide the basic environment for the directly productive activities and groups in a society	Ahmed and Donovan 1992, 3

Chapter 2

Infrastructure and International Conflict: A Theoretical Foundation

This chapter sets forth the theoretical reasoning for why infrastructure would play a role in international relations. This discussion begins by examining how technology in a variety of forms helps or hinders a state in achieving its goals. The second portion outlines how transportation and communication infrastructure improve three things: decreasing loss-of-strength, increasing transportation and coordination of supplies; and speeding up movement rates. The third section briefly discusses two additional benefits of infrastructure as a means to achieving a state's goals: lower opportunity costs and smaller responses from a state's neighbors and potential adversaries.

The fourth section of this chapter presents how state leaders incorporate advantages and disadvantages of infrastructure into their decision-making processes. The fifth section outlines six hypotheses for why transportation and communication infrastructure would influence the ability of states to achieve the goal of winning wars. The final section of this chapter discusses how transportation and communication infrastructure influence the ability of states to enter into or avoid international conflict. The discussion of state goals begins below.

Goals, Capabilities, and Technology

This discussion of infrastructure begins with the idea that state leaders have certain goals that they want to achieve, in both their domestic milieu and in the international setting. Some of these goals that leaders pursue involve international conflict. Leaders may want to maintain the current status quo or change something about their relationship with another state. Within that context, these state leaders can make several different choices in order to achieve a particular goal.[1]

The ability of a leader to achieve their goals will be shaped by their state's capabilities. The primary focus of existing research has been on the effect of relative national capabilities in achieving certain international goals. Measurements of these capabilities available for achieving state goals often come in two forms. The first form of national capabilities measurement revolves around the Correlates of War Composite Indicator of National Capabilities (CINC) measure (Bennett and Nordstrom 2000; Morgan and Palmer 1997, 2000). The second form of capabilities utilized in previous research is the financial resources of the state; Gross National Product (GNP) or Gross Domestic Product (GDP) are the most prevalent measures for this form of state capabilities (Bennett and Nordstrom 2000).[2] However, the resources that states possess to achieve their goals are not limited to these two aforementioned types.

---

[1] This idea comes from the literature on substitutability, introduced by Most and Starr (1984, 1989) and expanded upon by Morgan and Palmer (1997, 2000). For a greater review of this literature, there is a special issue of the *Journal of Conflict Resolution* that examines this entire research approach in greater detail.

[2] These are often taken as per capita measures.

Previous research has found that national capabilities play a very diverse role in shaping many forms of international conflict. National capability parity has promoted international conflict in all dyads (Bremer 1992) and enduring rivals (Geller 1993). Likewise, changing relative conditions of national capabilities have promoted war (Kugler and Lemke 1998; Organski and Kugler 1980).

Morgan and Palmer identify that *technology* is another factor that can influence the ability of states to achieve their goals (1997, 228). Broadly speaking, technology is a generally under-explored area of research in international relations. States can make technological changes and improvements in order to increase their probability of achieving their foreign policy goals. The history of international conflict is spattered with technological innovations that gave one state an advantage and made their goals more achievable during times of conflict. Innovations such as the longbow, gunpowder, telegraphs, aircraft, and even the most recent introduction of the computer have altered the international landscape (Van Creveld 1991). By possessing better technology than potential and realized adversaries, states have been able to accomplish a wide variety of goals in the international realm.

Nuclear weapons are one form of technology that a limited number of states have chosen in order to achieve the goal of state survival and security (Sagan 1997). Several states have chosen to construct nuclear weapons to accomplish certain foreign policy goals, including the United States, Soviet Union, England, France, China, Israel, Pakistan, India, and North Korea.[3] It is argued that these weapons promote the goal of state survival by making the potential costs involved with an attack on the state so high as to deter potential aggressors when in possession of nuclear weapons (Sagan 1997).

Leading Sectors Technologies are a second form of innovation that can shape or influence the ability of states to achieve their foreign policy goals (Modelski and Thompson 1995). Being the only state in the international system to possess a certain technology can give that state a distinct advantage over a potential adversary and an increased ability to achieve their policy goals. For instance, in 1999, the United States and other NATO countries determined that they were going to stop the ethnic conflict in Kosovo. Using their dramatic advantages in airpower, NATO was able to achieve its goal and end the ethnic conflict on the ground.

These two forms of technology both possess an important drawback for attaining state goals: their often extreme financial costs. Developing nuclear weapons and other leading sector technologies is often far too expensive for the majority of states in the international system. For instance, the U.S. recently capped the highly advanced F/A-22 “Raptor” fighter jet program at a total price tag of thirty-seven billion dollars, roughly equivalent to the entire GDP of Costa Rica in 2003 (“Tight Budgets” 2004; CIA World Factbook 2004). All states have limits in the amount they can spend in order to achieve their goals. Therefore, most states will be left to follow other technological paths in order to achieve their objectives. Rather than “breaking the bank” on nuclear weapons or

---

[3] It is important to mention that nuclear weapons have a very limited domain of foreign policy goals that they can help achieve.

leading sectors technologies, states can increase their probability of achieving their aspirations by acquiring technology on a more mundane level.

Infrastructure is one potential technological avenue that state leaders can utilize in order to achieve their goals. Other examinations have found that infrastructure already plays an important role in achieving some state goals outside the realm of international conflict. In Africa, infrastructure has been found to help promote citizen survival from both famine and civil war, a fairly basic goal of most states (Pirie 1995 and Myers 1994, respectively). Likewise, infrastructure also has been discussed as an important component of regime survival, another basic goal of most states in the international system (Englebert 2000). Finally, infrastructure has been shown to help promote economic growth, another important goal of many states (Shah 1992; Justman 1995; Linneker and Spence 1996; Morrison and Schwartz 1996).

However, state infrastructure has not been directly linked to goals of foreign policy and international conflict within the literature of international relations. In order to make this connection, it is first necessary to understand what infrastructure provides states and their leaders. Why is infrastructure beneficial? The next section addresses this question.

Benefits of Infrastructure

It is now important to develop the logic of why states would choose to develop infrastructure in order to increase their probability of achieving their goals. How and why would infrastructure appeal to states and their leaders as opposed to many of the other possibilities outlined above? The overarching idea behind why infrastructure influences the ability of a state to achieve their goals has to do with efficiency. Infrastructure shapes and influences the efficiency by which states can perform certain actions. Increasing this efficiency allows more capabilities to be applied to the problems at hand. More capabilities in dealing with a situation often mean a greater probability in achieving that particular goal. The next section will discuss three specific arguments how infrastructure increases efficiency.

Reduction in Non-Combat Loss-of-Strength

The basic act of moving military personnel and material is difficult on everyone involved. During wartime, there are physical costs to moving troops and material across large distances. This idea has been incorporated into international relations research before this project in the loss-of-strength gradient. The effect of distance has been included in models of international conflict when considering the distance between states (Boulding 1963; Bueno de Mesquita 1981). What these two authors were capturing was the loss of strength *between* states, where the capabilities of the state begin to diminish once outside the borders of the state in question.

Transportation and communication infrastructure will influence a state's loss-of-strength gradient *within* its own borders. Instead of only beginning to lose strength at the frontiers of the state (as Boulding and Bueno de Mesquita capture), military troops begin to lose their strength after leaving their military installations. Marching troops and tanks driving towards a battlefield can expect to lose members (and therefore lose strength) before ever engaging the enemy. This reduction means that there will be fewer military forces arriving at their intended location, making it more difficult to achieve a particular goal than if all the planned troops arrived at where they were intended.

An example of this consideration can be seen when considering modern military tanks. These vehicles are not designed to travel great distances on their own power. There are difficulties involved in keeping modern armored vehicles running and maintained. When comparing Warsaw Pact and NATO tanks during the Cold War, one study reported that: "…the T-62 has a breakdown every 160-200 km vs. every 240-300 km for the M-60A1" (Chalmers and Unterseher 1988, 37). A more modern tank, the United States M1 Abrams tank, also illustrates how difficult long distance mobility can be for these vehicles. In 1988, the tank tracks were redesigned; before this technological improvement, their life expectancy was 700 miles; after 1988 with the new tracks, on average they lasted for 2,094 miles (USNI Military Database 2004). In an interview about the M1 Abrams tank: "A U.S. Army tank commander told Periscope in October 1991 that his experience with the Abrams had been very positive…his tank had run 500 miles without a breakdown or any kind" (USNI Military Database 2004). These breakdowns will detract from the operational strength of a state's military. A state's security can be compromised if a large number of a state's tanks would break down before gathering at a threatened border or on a battlefield.

Transportation infrastructure systems reduce this type of troop loss dramatically, thereby increasing the number of troops that will successfully move from their home forts to the battlefield. More troops arriving on the battlefield increases the amount of military might that can fight the battles, thereby increasing the capabilities available for a given state to achieve its foreign policy and international conflict goals.

Increase in Movement and Coordination of Military Supplies

An often overlooked and underappreciated situation many militaries face is the vast quantity of supplies that they utilize in defending their respective states. The typical infantryman requires three thousand calories a day in order to function as a soldier (Van Creveld 2004, 1). Supply concerns are not limited to foot soldiers but also afflict tanks and other motorized vehicles. Fuel consumption is always a concern for these types of vehicles. According to several sources, the U.S. Abrams tank gets approximately one-half mile per gallon of fuel consumed (USNI Military Database 2004). In order to drive from Washington, D.C. to Los Angeles, each tank undertaking the trip would need approximately 5500 gallons of fuel.[4] Each tank on the journey would literally need its own tractor trailer of fuel in order to complete that drive.[5]

A contemporary example may help illustrate the potential difficulties associated in supplying an army. As of this writing (April of 2005), there are 140,000 US soldiers deployed to Iraq. Assuming every soldier eats three meals per day, the military needs to ship and coordinate the distribution of 420,000 meals per day. Assuming that every

---

[4] The War Department in 1919 commissioned a study of how long this exact journey would take. A young lieutenant colonel named Dwight Eisenhower was part of this project, which completed the trip in sixty-six days.

[5] This argument also applies to the vast quantities of other expendable items that a modern military requires to function, including ammunition and spare parts.

soldier requires one gallon of water per day, the US military apparatus needs to control the distribution of 140,000 gallons of water each and every day.

A military that is well-supplied on the battlefield will be able to fight more effectively than an army that is poorly supplied. Holding everything else constant, such as military strategy, troop strength, morale, and the host of other elements that can influence war fighting abilities, a well-supplied army will be better able to fight on the battlefield than an army that is poorly supplied. When an army is poorly supplied, the soldiers will have to spend more of their time foraging for the basic necessities of survival, such as food and water. A poorly supplied army may also have severe limits on the number of weapons available and the amount of ammunition they possess while a well-supplied army will be able to spend more of their time fighting their opponent, rather than spending their time providing for their own material necessities.

Increasing Speed of Movement and Communication

Infrastructure allows people and ideas to cross large distances more quickly than they could otherwise. Looking first at transportation infrastructure, to travel from Washington, D.C. to Los Angeles, California would take a walking person traveling twenty-five miles per day one hundred and nine days to complete the journey. The same route when covered by train would take fifty-nine hours, while it could be driven in forty-two. This trip would take a mere five hours by airplane. The effect of communications on speed is even more impressive. Sending information to troops or communicating with another world leader across great distances would take days, weeks, or even months if the correspondence had to be sent between capitals by messengers. With improvements in communications, information can be passed instantaneously over thousands of miles.

In times of conflict, speed can be a vital component of national security. A military that can quickly move from its home bases to a potential conflict zone can make an area that could have been a potential target much less appealing to a potential adversary. One author writes:

> …the side which manages to act first has greater freedom to choose the time, place, and manner of the battle. The slower side may then have to react to what its opponent has done, instead of pursuing more profitable objectives elsewhere. In other words, speed plays an important role in determining which antagonist will hold the strategic initiative.
> (Kane 2001, 8)

Maintaining this form of initiative is an important possibility for maintaining the security of the state. A state with good infrastructure can move quickly to exploit weaknesses in their opponent's defenses, or to modify their plans when they meet greater resistance than they originally planned. Likewise, a state with good infrastructure can potentially retreat when faced with a poor tactical situation, preserving their military forces for another battle at a different time if they possess the infrastructure to move them quickly out of harm's way.

Other Infrastructure Considerations

While these three benefits of infrastructure are important, there are not the only considerations of infrastructure. In addition to these three aforementioned elements of efficiency, there are two additional areas that can make infrastructure appeal as a way to achieve the goals of the state. First, infrastructure, unlike many other forms of state security, is useful in peacetime. Second, infrastructure possesses a smaller relative threat to a state's neighbors and adversaries than other choices that a state can make to achieve its goals. Each of these considerations will be examined in-turn below.

Useful in Peacetime

When leaders consider the means by which they work to achieve their goals, they must consider the opportunity costs associated with building or developing any form of capability that can help achieve a particular goal. Many forms of national capabilities come with high opportunity costs because they are single-use technologies or hardware. For instance, most military aircraft do not possess a civilian purpose or capabilities; tanks cannot be used to plow fields or move things from farms to markets. Simply stated, many pieces of military hardware only possess one purpose—warfare.

Infrastructure, unlike other forms of military hardware, is useful in peacetime and beneficial in achieving a multitude of state goals. The same railroad systems that can transport soldiers and other military assets in order to achieve a goal of security within the state can also transport food to the citizenry and goods to markets, helping achieve the goals of feeding a state's citizens or the goal of economic prosperity. The same telephone systems that can coordinate military actions can also send information for corporations, citizens, and a host of other domestic actors. Deciding to construct infrastructure therefore presents much lower opportunity costs to state leaders relative to many single-use technologies, making it an attractive avenue to help states achieve a variety of goals.

Smaller Relative Threat

One of the difficulties associated with the questions presented here is the problem of the security dilemma. As identified and described by Kenneth Waltz:

> "…states, unsure of one another's intentions, arm for the sake of security an in doing so set a vicious circle in motion. Having armed for the sake of security, states feel less secure and buy more arms because the means to anyone's security is a threat to someone else who in turn responds by arming. (1979, 186)

Many actions that states undertake to achieve their foreign policy goals can be interpreted by other states as a hostile overture. These other states would then respond by increasing their own assets, putting all the states back at the same relative point at which they started and therefore keeping the state at the same level of ability to achieve their goals.

Several cases of military modernization or nuclear weapons acquisitions have elicited strong international responses and concerns. North Korea has chosen to construct nuclear weapons in order to help promote their goal of state and regime security (*The Economist*, "When the Partying Has to Stop…"). The result has been a dramatic increase in tension between North Korea and many states, and both bilateral negotiations between North Korea and the United States, as well as more recent six-party talks with the United States, Russia, South Korea, Japan, China, and North Korea. Weapons modernization programs can also create international tension and hostilities in neighbors and potential adversaries. In early 2001, the United States announced a military arms sale with Taiwan, agreeing to sell Taiwan eight diesel submarines and twelve P-3 Orion antisubmarine aircraft to the island nation (*The Economist*, “Angering China”). China was angered and worried about the possibility of facing a better-prepared Taiwan.[6]

Infrastructure is a state improvement that causes relatively less insecurity, worry, and fear in one’s neighbors when compared to many other forms of capabilities that states can acquire and construct to achieve their goals. While infrastructure has been seen as a prelude to war and a cause for action and concern, it often elicits a far smaller response when compared to many of the other security options available to states. If North Korea had chosen to construct a new rail line within their borders, it may have drawn no attention if it was constructed near the Chinese border and garnered far less attention (as compared to the international crisis surrounding their nuclear weapons program) even if that railroad was constructed near the South Korean border. Similarly, if Taiwan had built better airports or improved their telephone system, it would probably have produced little response from their Chinese neighbors. Therefore, improving infrastructure can alleviate the security dilemma and cause less of a reaction when compared to other potential ways to achieve a state’s goals.

Leaders and Infrastructure Decision-Making

As established in the previous sections, infrastructure provides a number of potential benefits for a state in order to possibly achieve its goals. Military forces move faster, are better supplied, and arrive in better condition when a state possesses a better

---

[6] This worry and response could have been far worse. The US decided not to include top-end Aegis destroyers and PAC-3 tactical anti-missile systems into this package (*The Economist,* “Angering China”).

infrastructure system. The question now remains of how do leaders factor infrastructures into their decision-making processes. How do they evaluate their situation and act?

Understanding evaluations of infrastructure centers on the idea that leaders will concern themselves with relative infrastructure, in much the same way as they examine their broad national capabilities relative to the other states in their milieu (Morgan and Palmer 1997, 228). The aforementioned advantages in infrastructure make little difference in situations of potential (or realized) international conflict when considered in isolation. When examining bilateral relations, the advantages and disadvantages of infrastructure manifest themselves by creating differential rates of mobility, speed, and supply. Leaders can find themselves at advantages or disadvantages in terms of infrastructure, in much the same way as they can find themselves at an advantage or disadvantage in terms of military capabilities.

However, simply comparing relative infrastructure capabilities is not enough for understanding this situation. There is a second element necessary to consider in a leader's evaluations of decision-making: what broad type of goals the state leader wants to achieve. More specifically, does the leader of a state want to simply maintain the situation at hand, or do they want to institute changes in the current situation with another state. There would be behavioral differences in the actions and decisions of leaders depending on whether their goals are to either maintain or change the status quo with another state.

The following sections detail how leader's decisions (and thereby the behavior of their states) will differ under varying circumstances of infrastructure. The first section discusses the actions and concerns of leaders when facing disadvantages in infrastructure.

The second section outlines what sorts of decisions we can expect to see from leaders whose states possess an advantage in terms of relative infrastructure.

Relative Infrastructure Disadvantage

When a leader finds their state possessing a disadvantage in infrastructure but wanting to change the status quo, they will not pursue more bellicose policies at that particular point in time. In this set of circumstances, the leader of the state has identified a situation or problem that they want to change. They are dissatisfied over the status quo with another state, and would take action in order to alter this situation if the opportunity arose. However, in this situation the leader is at a disadvantage in terms of infrastructure. Their military forces will move slower to the battlefields, lose more strength in transit, and not be as well supplied (holding everything else constant) as their potential adversary with whom they want to alter the status quo.

In this set of circumstances, the state leader will not choose to initiate or become involved in a conflict against the potential target. They are disadvantaged relative to their potential adversary, thereby reducing their probability of both victory and the successful achievement of their goals. However, the leader's goal is still to eventually change the situation between the two states. In order to achieve this goal at some future point in time, the leader currently facing a disadvantage in infrastructure should pursue policies of building more infrastructures in order to shift the relative infrastructure balance more in their favor, thereby increasing their eventual probability of success. Their preliminary goal becomes the eventual conversion of their infrastructure disadvantage into a relative infrastructure advantage. If they achieve this antecedent goal of gaining an advantage in terms of relative infrastructure, then they can then act to achieve their original goal of making the changes to the status quo that they desire.

When state leaders find themselves at a disadvantage in infrastructure, but only wanting to maintain the status quo, they also will not pursue more bellicose policies. In these circumstances, the state in question will have a higher probability of being a target of a dispute or war. The state under examination is at a disadvantage in terms of infrastructure. Their military forces move slower than their potential adversaries; their troops are less likely to be supplied efficiently during wartime, and they will suffer a greater loss of military strength when moving their troops (again, when holding everything else constant). These disadvantages therefore make the state more vulnerable by making them appear more attractive as a target.

Under these conditions of infrastructure disadvantage, the presence or absence of conflict is not a decision made the leader of the state, but by the leaders of the states in possession of infrastructure advantages over the state in question. The decisions come down to whether or not the outside states and their respective leaders are satisfied with the status quo. If these other states are only interested in maintaining the current relationship between the two states, then there will not be conflict between them. If the opposing leaders have the goal of altering the existing relationship, then there should be a higher probability of conflict between the two states as outside forces initiate against the state at a disadvantage in relative infrastructure.

Relative Infrastructure Advantage

This discussion now turns to what happens when a state possesses an advantage in relative infrastructure over another state. In the previous discussion of disadvantaged situations, state leaders had fewer decision options regarding what sort of policies and actions to undertake in order to achieve their goals. When a state's leader perceives that they possess advantages in relative infrastructure, then their menu of possible options expands.

When a state only wants to maintain the status quo and possesses an advantage in infrastructure, the leaders of these states will not pursue more conflictual courses of action. In this set of circumstances, the state has an advantage over its potential adversaries. However, they also do not want to alter the status quo with the other state. Infrastructure in this circumstance provides a general deterrent effect (Huth and Russett 1993; Huth 1988; Morgan 1983). When a state possesses an advantage in infrastructure, other state leaders will not be as inclined to become involved in military action or conflict with that state because they will find themselves beginning the conflict at a disadvantage. The military forces under their control will move slower, their troops will be less well supplied, and they will arrive at the battlefield with fewer troops than they started with, ceteris paribus. Because of these disadvantages, state leaders will be deterred from becoming embroiled in international conflict with the leader whose state possesses the infrastructure advantage. Therefore, this should make potential adversarial leaders reconsider their courses of action and make them less likely to initiate against the state in question.

When the state possesses an advantage in infrastructure and wants to change the relationship or status quo with another state, then that leader will be more likely to initiate international conflict in order to bring about the changes they want. Their state possesses the infrastructure advantage over another state. Their military forces will be able to maintain the tactical advantage by being able to move faster than their potential opponent. Their forces will arrive at a potential battlefield in better order and be better supplied than their potential adversary. Under these circumstances, the state possessing this advantage would have a higher probability of choosing to exploit that advantage and become involved in military conflict with another state.

With these generalizations is place, it is now important to move from generalities to more specific, observable goals that states can attempt to achieve through infrastructure. The following section will discuss how infrastructure can help a state achieve one important goal—victory in war. The section after that will examine how infrastructure influences a second goal—the initiation or avoidance of international conflict.

Infrastructure and War Outcomes

The first goal concerning international conflict under examination in this research project is how victory or defeat in war is influenced by the presence or absence of infrastructure. While most states will want to avoid war in the first place, state leaders can find themselves embroiled in a war. Given that the states are fighting a war, all state leaders in the international system should possess a goal of winning the war. States that lose wars have to deal with many possible negative ramifications. They can lose territory, they can have settlements imposed against them, have their regimes forcibly removed by their adversaries, have the government overthrown or replaced by domestic groups for losing the war, or even lose total sovereignty as the state is conquered and assimilated into a conquering foe. Conversely, states that win wars can maintain the status quo or impose some, any, or all of the aforementioned negative consequences upon a vanquished adversary. “To the victor go the spoils.”

A large number of ideas have been advanced that influences the probability that a state will achieve their goal and win a particular war: initiation, regime type, capabilities, troop quality, terrain, and military strategy are many of the primary factors attributed to war outcomes.[7] While there are a great variety of explanations, there has not been a systematic explanation or an empirical test of how state infrastructure will influence winning or losing wars. In the section that follows, I present six testable hypotheses that identify and develop the relationship between infrastructure and war outcomes. The first two hypotheses detail and discuss how the relative levels of transportation and communication infrastructure between warring states influences the probability of winning a war. The third and fourth hypotheses discuss how transportation and communication infrastructure will diminish in importance as the distance between the state and the battlefield increases. The fifth hypothesis will examine the role of

---

[7] See Reiter and Stam (1998) for a more detailed discussion of these previous research endeavors.

transportation infrastructure both before and after World War One. Hypothesis six will examine communication infrastructure both before and after World War One.[8]

Hypothesis One: States with greater relative transportation infrastructure over their opponents have a higher probability of winning wars.

Transportation systems are the first component of infrastructure that can influence war outcomes. As described earlier, infrastructure provides speed of movement, better coordination of supplies, and a reduction in loss of strength within a single state. Examining two warring states where both adversaries possess the same level of infrastructure, these enemies would move equally quickly, coordinate their military supplies at the same rate, and lose approximately the same amount due to moving troops within their own borders, holding everything else about the warring states constant. When we see one state possessing a greater degree of infrastructure than another state, the state with higher levels of infrastructure will move their military forces more quickly, better coordinate their supplies, and lose fewer troops prior to fighting their opponent than their adversary with a lower level of infrastructure. These advantages for the state with better-developed transportation infrastructure will promote war victory.

Another reason advantages in relative transportation infrastructure increases the probability that a state will win a war has to do with the relative amount of physical damage a state can withstand and still continue to fight.[9] In many wars, one of the first things targeted is infrastructure systems. "In planning and conducting war the industrial

---

[8] While there are potentially additional hypotheses, such as interactive effects between infrastructure and national capabilities, research design issues (which are directly addressed in Chapter Four of this dissertation) did not allow for rigorous empirical testing of other hypotheses.

[9] This logic also applies to communication infrastructure as well.

establishments of a nation could well be primary strategic targets as each side in war seeks to cripple the other's capability to support the war" (Newell 1991, 101). Railroad crossings, bridges, telephone switches, and power plants are often destroyed as targets during conflict and war. When a state has an advantage in terms of infrastructure, they have the ability to absorb and maintain their advantage. They have the capacity to suffer more damage to these systems and still have these systems function when compared to their adversary. While damage will reduce their effectiveness, these systems will still function at a greater level than their adversary, maintaining their advantage. In a state with poor infrastructure, facing a disadvantage in transportation infrastructure, any damage to their transportation systems could cripple their ability to support and maintain their military forces against an opponent, thereby severely limiting their ability to fight and eventually win the war. Having an advantage in these systems at the commencement of a war will give that state an advantage as these systems come under attack during the course of a war.

It is important to make one final comment regarding transportation infrastructure. Some may argue that the transportation infrastructure in the specific location of the fighting plays a much more important role than the overall infrastructure of the warring states. For example, when $State_A$ fights against and within $State_B$, which possesses excellent infrastructure, entering and occupying $State_B$ could make it much easier to defeat that state by utilizing the state's assets against them. On the flip side, there are states where the lack of infrastructure can make war victory more difficult. Invading a state with little or no infrastructure means that the invading state will have to find ways to transport and coordinate their efforts without the presence of infrastructure, hindering their ability to win that war.

The events of World War One provide a historical analogy to help illustrate this potential concern. When planning the invasion of Belgium in order to circumvent the French fortress system, Germany examined and attacked the strategic city of Liege because of its superior transportation infrastructure. "…Its junction of four railroad lines connecting Germany and Belgium with Northern France was essential to the supply of the German armies on the march" (Tuchmann 1994, 164). Invading Russia, however, posed two distinct hindrances of poor infrastructure for a war and invasion. First, Russian railroad tracks are a different gauge than railroad tracks in the rest of Europe. Second, Russia had far less transportation infrastructure than other European states: "Russia had available one-tenth as many railroads pre square kilometer as Germany" (Tuchmann 1994, 58). Therefore, Russian transportation infrastructure would serve as a hindrance to Germany when they invaded Russia, thereby making them harder to invade and harder to defeat, thereby shaping the eventual outcome of this war.

While these arguments make intuitive sense, they are not considered nor tested in this treatment. The infrastructure measures and the arguments here examine the transportation (and communication) infrastructure of the warring states prior to the commencement of hostilities and do not consider transportation and communication systems once a war has commenced. The data presented here are not refined enough to capture the ebb and flow of transportation and communication infrastructure during the course of a war. This problem of using only information right before a war and not information that is updated during the course of a war, is an issue for the entire literature on war outcomes, and is not limited to the analyses presented here. While it would be very important to eventually examine infrastructure as a war progresses, it is beyond the scope of this current research project.

Hypothesis Two: States with greater relative communication infrastructure over their opponents have a higher probability of winning wars.

The need for communication infrastructure cannot be understated: "Communications between commanders who view war from the operational and tactical perspectives…is as important as any other aspect of planning and conducting war" (Newell 1991, 103). Without a communication system in place, troops may sit idle, unengaged, and awaiting orders while the battle or the course of a war may turn in favor of an opponent, resulting in defeat and other dire consequences.

Communication infrastructure allows a state to better coordinate the efforts of its military during times of war when compared to their adversary, thereby increasing the probability that a given state will be victorious. Two states with identical communication infrastructure systems will be able to send communications at the same rate, possess the same abilities to coordinate their militaries, and order military supplies at the same rate, again holding everything else constant. In this situation, communication infrastructure would give both sides in the war the same degree of communication and information, and therefore be a "push" in terms of war outcomes. When one state possesses a larger, more advanced, and better communication infrastructure system than its wartime adversary, then this state will begin to realize and be able to exploit some of its advantages. The state with better communication infrastructure can order supplies more efficiently, requisition replacement troops faster, and send warnings of potential attacks and counterattacks to the troops that need the information than its adversary.

A second important connection between communication infrastructure and war outcomes has to do with the nature of war itself. During the course of a war, states must update their tactical information between military leaders and between military leaders and the political leadership. Are they winning the battles? Do they need to advance or retreat? States and their actors at various levels update and change their information to more accurately reflect the realities by which they are faced through their communication infrastructure. The networks of telegraphs and telephones that form communication infrastructure will speed information in real time among battlefield commanders and from military command centers to the political leaders of the state.[10] In states with well developed communication infrastructure, this ability to communicate well and quickly increases operational flexibility allowing a state to modify its war practices and aims quickly, thereby allowing the state to fight the war more effectively. In states with poor communications systems, this updating will take place at a much slower rate than in states with better infrastructure systems. A state with poor or non-existent abilities to update their battle plans (due to non-existent infrastructure) will have to fight perhaps the entire war by the original battle plan as it was drawn up with little modification. Poor, weak communications flows (created by a lack of communication infrastructure) make victory in wartime more difficult.

Hypothesis Three: As geographic distance to the war zone increases, the effectiveness of relative transportation infrastructure in winning wars will decrease.

---

[10] Transportation infrastructure can also perform this task; however it does not perform it in real time.

Hypothesis Four: As geographic distance to the war zone increases, the effectiveness of relative communication infrastructure in winning wars will decrease.

As the geographic distance between the warring state and the battlefield increases, the influence of state infrastructure within the warring state should matter less to war outcomes. In its place, the importance of power projection capabilities will play a greater role in order to overcome the effect of increasing geographic distance. When examining two contiguous states, the level of their respective transportation and communication infrastructure should make the most difference in determining who wins and loses the war between them. However, when we assume that they are no longer contiguous, there will be a growing importance of power projection capabilities. While the ability to move and communicate within the warring states will still play a role in shaping the outcome of a war, that ability to move and communicate within the state will be far less important when the difficulties involved in moving those troops long distances between states are considered and taken into account.

A historical case can illustrate this point. Over a period of ten years, France was involved in several interstate and extra-systemic wars. In 1940, they fought and were defeated by Germany, a state contiguous to the French homeland. By December of 1945, France was sending troops and fighting an extra-systemic war in Indochina. By March of 1947, French troops were also fighting an extra-systemic war in Madagascar (Sarkees 2000). While the point of French and German infrastructure considerations is well-documented, it does not make as much intuitive sense for the infrastructure of mainland France to matter as much for a war fought in Madagascar or in Indochina. The intuition here is that the infrastructure of the home state should not matter as much as the distance of the war increases. Therefore, the consideration of distance should play a more prominent role and infrastructure should play a diminished role as the geographic distance increases.

Hypothesis Five: Relative transportation infrastructure is a smaller determinant of war victory after World War One.

Not all relationships in international relations are constant across time; some previous research efforts argue that certain phenomena are isolated to a particular era.[11] It is possible that there are differences in the influence of the role and importance of transportation infrastructure over time. From the 1830s until the end of World War One, the major school of thought for warfare focused on railroad management. "…every general staff hastened to add a railway department to its structure. Since service in these departments required extensive mathematical knowledge, they attracted the *crème de la crème*" (Van Creveld 1991, 159). When the major school of thought concerns transportation infrastructure, and the heads of most general staffs were experts in transportation and logistics, then it would follow that these considerations should play a highly important role in shaping war outcomes during this time period.

After World War One, however, there was a diminished focus on these sorts of systems and plans. Many of the characteristics that had made military leaders desirable before this war simply went out of focus after the four-year stalemate of World War One. While logistics would still be important and play a significant role in shaping war

---

[11] For instance, Farber and Gowa argue that the democratic peace proposition is a phenomenon isolated to the Cold War era (1995, 124).

outcomes, the dominating focus on transportation infrastructure of the Pre-World War one era was no longer in place and not as important as it once had been.

A counterargument could be made that transportation infrastructure systems are in fact more important after World War One than before it. The central line of thought for this proposition has to do with the changing nature of war over that same time period. Before World War One, there was far less diversity in the military material necessary to fight a war. Troops needed food, ammunition, and spare parts for rifles. After World War One, however, the variety of military material necessary to keep an army in the field increases dramatically with the rise of mechanized militaries. Modern armies often utilize several different types of fuel (diesel fuel, aviation kerosene, and basic gasoline), have dizzying numbers of spare parts that are necessary in order to keep their wide variety of vehicles operating in combat conditions.

This counterargument can easily be tested along with Hypothesis Five described above. If this counterargument is correct, and transportation infrastructure in fact is more important after World War One, then the coefficient for the post-World War One transportation infrastructure variable in the statistical model should be positive instead of negative.

Hypothesis Six: Relative communication infrastructure is a larger determinant of war victory after World War One.

Generally speaking, states are less likely to rest their success or failure on unproven technologies in any endeavor, let alone one as potentially important as state survival when fighting a war. When a certain technology is invented, there often is a period of time when it is considered unwieldy and useless to the state. Over time these new innovations can be integrated into the military, planning, and apparatus of the state. Many technological innovations that are considered commonplace today were one marginalized and even ridiculed, including the tank, airplane, and the aircraft carrier.[12]

Communication systems were considered rather unreliable for an appreciable period of time during the study presented here. In the time period before World War One, communication infrastructure was somewhat fragile and therefore considered unreliable. One author writes:

> The Germany army officer corps…displayed suspicion to technology in its resistance to the telegraph and its slow adoption to the telephone. The German army's weakness in the use of telecommunications contributed to its failure at the first battle of the Marne…Comparable problems plagued the Austro-Hungarian military in July 1914: the Habsburg government found that a lack of communication equipment prevented it from launching the quick attack on Serbia that, it hoped, would produce a fait accompli and avoid a world war. (Nickles 2003, 115)

Therefore, during the time before World War One, state militaries and state leaders should place little emphasis and confidence in these systems. They were largely considered unreliable, and therefore not be considered as methods to help promote war victory.

However, after World War One the reliability of communication infrastructure improves dramatically. Inventions and wide-spread distribution of automatic switchboards, wireless systems, and greater overall reliability made these systems more reliable and therefore more important (Oslin 1992; Winston 1998). Once these systems are more reliable, then they mad their way into greater and more pronounced service in

---

[12] There are discussions about whether or not the time of the tank has come and gone. Current U.S. Defense Department discussions are trying to determine whether the tank has as prominent a position in the low-intensity conflicts that face the U.S. today.

the militaries of the states in which they operated and therefore would make a more pronounced difference in the outcomes of wars after World War One.

Infrastructure and Militarized Interstate Dispute Onset

While winning a war is a desirable and important state goal, there are several reasons to expand the scope of empirical examination and look at more broad instances of state behavior. First, wars are fairly rare events. While there are more than two thousand militarized interstate disputes between 1816 and 2001, there are only seventy-nine wars from 1816 until 1991 (Ghosn, Palmer, and Bremer 2004 and Sarkees 2000, respectively). Second, even winning wars imposes very high costs for the state. There are high costs for the state in terms of lives and money when their state's military is successful in defeating an adversary. State leaders often would rather avoid the high costs of war altogether (while producing the same result) rather than fighting a successful war against an adversary.

With these two considerations in mind, it is therefore useful to examine the beginning of international conflict. Lesser militarized conflicts are much more common events than wars. In addition, because leaders of states should want to avoid (or at least minimize) the high costs associated with militarized conflict whenever possible, it is important to examine the beginning of militarized interstate disputes to see what leaders can do to alleviate these potentially high costs. This section will set forth twelve hypotheses regarding state infrastructure and militarized interstate dispute onset.

Hypothesis Seven: States with an advantage in relative transportation infrastructure over their potential opponent have a higher probability of initiating a militarized interstate dispute in a given year.

Hypothesis Eight: States with an advantage in relative communication infrastructure over their potential opponent have a higher probability of initiating a militarized interstate dispute in a given year.

When deciding to initiate an interstate dispute, state leaders will examine the balance of transportation and communication infrastructure systems between themselves and a potential adversary, determining the relative level of these systems. When there are advantages in either transportation or communication infrastructure, these advantages can translate into international conflict. These ideas parallel the idea of *opportunity* set forth by Most and Starr (1993). They write: "Technology can help produce capabilities that modify distance and other aspects of the physical opportunities presented by geography (Most and Starr 1993, 31). Large differences in infrastructure systems provide states with "windows of opportunity" for the initiation of interstate conflict (Lebow 1984). [13]

When a state finds itself with an advantage in terms of infrastructure (which means they have more infrastructure than a potential adversary), then they should have a higher probability to exploit this advantage and initiate a militarized interstate dispute against their potential target. The state possessing the advantage will be able to mobilize its military forces more quickly than its potential adversary. Likewise, this quickly-mobilized military force will be better supplied and will lose a lesser amount of military might due to its movement from its home bases, holding everything else constant. With

---

[13] The windows of opportunity that Lebow was originally talking about were windows of opportunity regarding nuclear weapons. However, I am arguing here that infrastructure can create more conventional windows of opportunity for states to choose to jump through.

these advantages in hand over the state with the lesser degree of infrastructure, the state with better infrastructure will be more likely to initiate a militarized interstate dispute against the other state because of the higher probability of victory due to the benefits created by their infrastructure advantage.

In cases where there is little difference between the transportation and communication infrastructure of two potential disputing states (a situation of relative infrastructure parity), there is little opportunity presented through infrastructure. Both sides will move their forces just as quickly, re-supply them with the same efficiency, and face the same degree of military loss of strength, holding everything else constant. This degree of sameness between the two potential adversaries would therefore not present an opportunity through an advantage in infrastructure, and should result in no observable increase in international conflict propensity.

In cases where a state leader examines the relative infrastructure between their state and a potential target and finds that the infrastructure balance is not in their favor, then there should be a greatly reduced probability of initiating a militarized interstate dispute in that year. Because the leader of the state can observe that their potential target will move more quickly than the forces of their respective state, will be better supplied, and will lose less troops moving to the battlefield, there will be a reduced probability of success if they were to initiate a dispute against that particular state. In this set of circumstances, the infrastructure systems of their potential target would provide a deterrent effect and therefore reduce the probability of conflict initiation in a given year.

For an example of this type of thinking, these sorts of infrastructure considerations manifested themselves just prior to World War One. By 1914, General von Moltke's staff "developed a credo, based on a careful count of Russian railway mileage, that Russia would not be 'ready' for war until 1916" (Tuchman 1962, 27). This preponderance of Germany railway systems, combined with a perceived lack of readiness in Russia made the German General Staff more bellicose and more likely to recommend and pursue conflict behavior. With a reduced threat of a powerful Russian response from the east (due to poor infrastructure in the form of railways), the German General Staff held that a war in Europe in 1914 would more closely resemble a one-front war, a situation much more suitable to German success and potentially victory. With a higher probability of success, German policies in 1914 were much more confrontational than if they were more evenly matched with their Russian counterparts.

Hypothesis Nine: Relative transportation infrastructure is a larger determinant of militarized interstate dispute onset before World War One.

It is possible that transportation infrastructure could exhibit differing effects over time when considering the initiation of militarized interstate disputes. Military institutions (which were often the same as or in close contact with their civilian leadership) provide their respective state's decision makers with information on relative strengths and weaknesses on a variety of different factors. Before World War One, the military apparatuses of states were highly concerned with their relative transportation infrastructure (Van Creveld 1991). Because of the focus on transportation infrastructure in military institutions during that time frame, leaders would have been more likely to be provided railroad and mobilization estimates on which to base their decisions.

A historical example can help illustrate this preoccupation with transportation infrastructure. From 1892 – 1913, European states adopted an offensive mindset, eventually called the "Cult of the Offensive" (Van Evera 1984, 59). During this time frame, military and political leaders were focusing their attention on four technologies that were thought to give them an advantage on the battlefield and promote victory: rifled and repeating arms, the machine gun, barbed wire, and railroads (Van Evera 1984, 58).[14] Military leaders would be more inclined during this time frame to examine whether the army of a potential adversary possessed rifled or repeating arms, their relative number of machine guns, or the relative amounts of transportation infrastructure between the two states. This preoccupation with these elements during this timeframe would thereby color the decisions of state leaders.

After World War One, this focus on infrastructure declines from its pre-War level of consideration. The massive railroad mobilization plans that dominated the pre-World War One era were supplanted by more tactically-oriented innovations, such as the increased focus on the "Blitzkrieg" strategies employed by Germany to overtake many of its European neighbors (Van Creveld 1991). However, it is important to mention that transportation infrastructure should still play a significant role after World War One; armies still need ammunition, food, water, and other provisions in order to operate. However, this central focus on transportation infrastructure as not as much of a consideration after World War One than before this particular war.

Hypothesis Ten: Relative communication infrastructure is a smaller determinant of militarized interstate dispute onset before World War One.

---

[14] Van Evera originally compiled this list. It is unclear how barbed wire fits in as an offensive component with the other three components listed here.

Much like its transportation counterpart and its related hypothesis concerning war outcomes, it is possible to argue that there are differing effects for communication infrastructure over time. Unlike transportation infrastructure, however, communication infrastructure increased, rather than diminished, in importance after World War One.

Most states will not make decisions on or place their security in the hands of systems or concepts that are considered to be unreliable. Systems that are unreliable in peacetime would have a greater probability of failure in the difficult environment of international conflict or war. Communication infrastructure was generally far more unreliable prior to World War One than it was after that particular war. Since communication systems had reliability issues before 1918 under the normal day-to-day conditions of peacetime (Nickles 2003; Oslin 1992; Winston 1998), it would not outwardly appear that they should factor prominently into considerations of conflict initiation when those fragile systems would be placed under extreme amounts of stress during times of international conflict.

Communication infrastructure became much more reliable and integrated into the societies and the military apparatuses of states after World War One. Since they were more reliable and commonplace, these systems would then be seen as a more integral and important component of states. Therefore, before World War One, communication infrastructure should play a diminished role in shaping conflict initiation, while communication infrastructure should play a far grater role in the initiation of interstate conflict after World War One.

Hypothesis Eleven: The magnitude of relative transportation infrastructure for initiating a militarized interstate dispute increases when the states are contiguous.

Hypothesis Twelve: The magnitude of relative communication infrastructure for initiating a militarized interstate dispute increases when the states are contiguous.

One of the most studied relationships in empirical international relations is how geography shapes international conflict. Contiguity (Vasquez 1993) and territory (Hensel 1996) are two of the most common explanations for interstate conflict behavior. Considerations of infrastructure may also be shaped by factors of geography. When deciding whether or not to initiate a militarized interstate dispute against a particular state, infrastructure should play less of a role in decision making (and therefore conflict initiation) as the distance between the states increases.

In a dispute between two contiguous states, the effect of infrastructure should be highest because every location within either state is a potential point of attack. When the states share a common border, they have direct access to each others borders, thereby not needing large navies nor other power projection assets in order to attack each other, making their internal infrastructure most important when the potential states are neighbors. The infrastructures of the potential disputing states provide opportunities to attack from a multitude of places within the neighboring states. When two states are contiguous, the ability of a state to project power across large distances between states is at its smallest relative importance.

However, when there is some amount of geographic distance between a potential initiator and a potential target, the potential initiator's power projection abilities and capabilities (such as naval transport) will become a more important relative consideration of conflict. While there will still be some role for infrastructure systems, as troops still need to move from their bases to points of embarkation, the internal infrastructure of the state is not as critical in situations when the states are not contiguous. This reduction in importance of infrastructure, and increased importance of power projection capabilities, would thereby reduce the overall influence of transportation and communication infrastructure when the states are not contiguous.

Hypothesis Thirteen: Relative transportation infrastructure is a larger determinant of militarized interstate dispute onset for "Western" states.

Hypothesis Fourteen: Relative communication infrastructure is a larger determinant of militarized interstate dispute onset for "Western" states.

It is possible that infrastructure is only a consideration when deliberating the initiation of an international dispute in "Western" states—The United States and Europe. Previous research in international relations has found that some relationships only exist or operate in certain regions of the world.[15] In researching these ideas surrounding infrastructure, there were no apparent writers, stories, or anecdotes that came from South America, Africa, or Asia. The vast majority of writers and thinkers on this subject of infrastructure and taking advantage of its benefits were almost all of European descent.

Because of this general observation, it is possible that the thoughts, teachings, and considerations of these leaders did not find their way out of Western societies. While they may have been very important in Germany, France, and Russia, it is not altogether clear whether these thoughts and approaches to conflict and war made their way into other regions of the world. If there were authors or political leaders around the world preaching the importance of infrastructure, then it would appear that this may be a generalizable phenomenon to all states. Since there does not appear to be any concrete

[15] For example, Henderson argues that the democratic peace proposition is isolated to only Western European states and does not apply to Africa (1998).

work examining these systems outside Western societies, it may be possible that the effects of transportation and communication infrastructure are limited to only these states and not generalizable across all the states of the international system.

Hypothesis Fifteen: Positive changes in relative transportation infrastructure increase the probability of initiating a militarized interstate dispute.

Hypothesis Sixteen: Positive changes in relative communication infrastructure increase the probability of initiating a militarized interstate dispute.

While the static situation of infrastructure between two states may be a reason for conflict and war, the dynamic, changing picture of relative infrastructure may also influence decisions on initiating interstate disputes. A changing environment of relative infrastructure may make leaders more likely to initiate a militarized interstate dispute. This idea parallels the power transition theory, where changes in national power between the hegemon and a rising challenger can lead to war (Kugler and Lemke 1998; Organski and Kugler 1980). Changes in relative transportation and communication infrastructure between two states may be an invitation to conflict.

As discussed earlier, states may find themselves wanting to change something about their relationship with another state. In addition, they may also find themselves at a disadvantage in terms of infrastructure. In this set of circumstances, the hypothesized prescription for achieving that eventual change in the status quo would be to construct more infrastructures, thereby swinging the balance of infrastructure more in favor of the dissatisfied state, and the eventual initiation of a militarized conflict in order to achieve that goal of changing the status quo. Therefore, when the balance of infrastructure is shifting more in favor of the potential initiator, we should see a greater probability of militarized interstate dispute initiation.

On the flip side of this argument, if the balance of infrastructure between the states is negative, indicating that State A's relative infrastructure position is worsening, then there should be less likelihood of initiating a militarized interstate dispute in a given year. The advantage for State A is slipping away, thereby reducing the probability of their success. In this set of circumstances, there should be a lower probability of militarized interstate dispute onset.

History provides an example of this sort of concern. In his speech to the Politburo in 1937, Stalin warned that Germany and Italian railroad construction was a prelude to war (Rees 1995). Stalin took these increases in transportation infrastructure as an indication that Germany was becoming more physically able to initiate a conflict with its Soviet neighbor, thereby resulting in a tenser international situation, and therefore these railroad constructions were considered by the Soviets as a prelude to possible international conflict.

Hypothesis Seventeen: There is a positive interactive effect between relative transportation infrastructure and national capabilities on the probability of initiating a militarized interstate dispute.

Hypothesis Eighteen: There is a positive interactive effect between relative communication infrastructure and national capabilities on the probability of initiating a militarized interstate dispute.

The final two hypotheses examine the relationship between national capabilities and infrastructure. While having an advantage in infrastructure may be important, that advantage may mean little if there is not the military might available to use that advantage. Likewise, if a state possesses a massive military apparatus, it may be unable to use it to initiate a militarized interstate dispute if that military is barely able to move within the state, let alone operate against another state.

An advantage in military or state strength can be considered an advantage in *capabilities*. The state in question has the material capabilities (such as a large army) to act against another state should it decide to do so. An advantage in transportation or communication infrastructure can be considered an advantage in *capacity*. A state with an advantage in infrastructure would have a greater capacity than a potential adversary. While having an advantage in either capabilities or capacity may give the state a greater opportunity to win a particular conflict, the most dangerous potential situation should be when a state has an advantage in *both* capacity and capabilities.

Examining Europe before World War One can help to illustrate this idea. Belgium, a state often considered to possess high levels of infrastructure (due to its small size), held an advantage in capacity. However, because Belgium only had a small army (48,000 members in 1913), they would not have possessed an advantage in capabilities and the result of this situation is that Belgium would not be as conflict-prone as other European states during that era.[16] Russia, on the other extreme, possessed one of the largest armies in the world (1,286,000 members in 1913), giving them a distinct advantage in capabilities. Their poor transportation and communication infrastructure systems would denote a lack of capacity and therefore make them somewhat less prone to conflict than other European states. In between these extremes, Germany would appear to be a European example of the state to be most concerned with because they possessed both capacity and capabilities during the Pre-World War One era. Germany possessed

---

[16] These numbers come from the Correlates of War National Material Capability data set (Singer, Bremer, and Stuckey 1972). I use 1913 for a comparison point because the data for 1914 – 1918 reflect the mass mobilizations for World War One, however these comparisons are also suitable using data from any year between 1900 and 1917.

both a sizeable military apparatus (859,000 members in 1913) representing high capabilities and a well-integrated infrastructure system which represented high capacity, resulting in a more potentially conflict-prone state.

Conclusions

This chapter has set forth the idea that state leaders have a variety of goals that they want to achieve, and that goals surrounding international conflict are one subset of those goals. Leaders will examine the differences in relative infrastructure when making decisions regarding what actions their state should take in order to achieve their goals. Those differences in relative transportation and communication infrastructure can promote victory in times of war, and can promote or deter the initiation of militarized interstate conflict. With this theoretical foundation in place, the next logical step is to empirically test these hypotheses. In order to conduct that testing, it is necessary to construct a data set for both transportation and communication infrastructure. The next chapter discusses the data on infrastructure.

Chapter 3

Measuring Infrastructure

After presenting a number of testable hypotheses in the previous chapter, the next step is to empirically test these assertions and see if the evidence supports or refutes them. In order to perform these statistical tests, it was necessary to collect data on transportation and communication infrastructure. This chapter explains how I did that, setting forth the first multi-indicator longitudinal data set measuring transportation and communication infrastructure for all states in the international system from 1840 until 1993.

This chapter contains four major sections. The first portion of this chapter identifies the raw measures that contribute to my two final indicators of infrastructure. This section presents a brief historical overview for each indicator, and discusses (and dismisses) alternate indicators for each. The second section in this chapter discusses the process of taking five dissimilar indicators of infrastructure and amalgamating them into composite indicators of transportation and communication infrastructure. I discuss the use of densities rather than the raw indicators, and offer an in-depth discussion of the decision to use factor analysis to create these two composite infrastructure indicators.

The third section of this chapter presents some general descriptions of the data, examining such things as the mean, standard deviation, minimum and maximum values. The final portion of this chapter performs some initial, rudimentary empirical examinations of the two infrastructure measures in order to see if they demonstrate validity. This data testing section begins by examining the correlations between these new measures and many other common measures utilized in international relations. The empirical testing also compares the data's time series correspondence to historical events for a particular state (in this case, Germany) in the international system, seeing if changes in the historical record correspond with observed changes in the two infrastructure data series. The data are then used to make predictions about international conflict behavior (in these cases, war outcomes) where previous measures of interest in international relations have failed to make accurate predictions. Finally, the infrastructure data presented here are compared to statistics from a global region that oftentimes contains data limitations and difficulties—Africa. The raw indicator discussions begin next.

Raw Indicators of Infrastructure

The first step necessary in generating a composite indicator of transportation and communication infrastructure was to identify the broad components that would capture the growth (or decay) of these systems over the 153 years of this project. To this end, three indicators of transportation infrastructure and two indicators of communication infrastructure were selected in order to accurately measure these phenomena. All the data for these five indicators come from the *International Historical Statistics* volumes published by Mitchell (1998). This section presents the indicators for transportation infrastructure first, followed by those for communication infrastructure.

Transportation Infrastructure

Transportation systems are the first element of infrastructure that I measure and quantify. Over the past two hundred years, there have been three primary modes of transportation that have proved essential to capture in any analysis: railroads, automobiles, and air travel.

Railroad Kilometers

Since its invention in the early Nineteenth Century, the railroad has proven to be one of the more important forms of transportation infrastructure. This mode of transportation is able to carry large quantities of people and material across long distances without the need for either human or animal power. Also, railroad systems can carry dramatically more weight than their automotive or airplane counterparts. While other forms of transportation have come into existence, railroads are still an essential element of the transportation infrastructure of states in the international system (Channon 2001).

The length of railroad track in kilometers within a state in a given year is the measure utilized to capture the prevalence of railroads within a particular state in this data set. These yearly data allow this measure to capture changes in railroad length, indicating even the smallest degrees of change in railroads over time. High values of this measure indicate a large amount of railroads in a state while a small number indicates a very small amount of railroad infrastructure.[1]

Two alternative measures of railroad assets exist that were unsuited for utilization in this research. The first measure is the number of passenger-kilometers that a state's railroad system managed to move people. This is a measure that looks at both the number of people and the distances they traveled on a state's railway system. A large, well developed railroad system would be able to carry a high number of passengers across very long distances, represented by a high passenger-kilometer value for a particular year. The second alternative measure is the metric tons of freight per kilometer transported by railroad systems. In much the same way as the passenger-kilometer, these data examine utilization and capacity rather than merely the presence or absence of a railway system.

Both of these alternative measures were beset by a problem that made them unsuitable for this project: there is only a limited amount of data available for both alternate indicators. Freight and passenger-kilometer traffic data are only available for a sample of states, providing data coverage of Western Europe, the United States, and other states identified as "Great Powers" according to the Correlates of War project (Mitchell 1998). While these alternative indicators would measure this characteristic for the largest players in the international system, they would fail to measure the railroad capacities for the vast majority of states within the international system. Therefore, these alternatives

---

[1] All infrastructure analyses rely on measuring the density (infrastructure pre square kilometer) of the infrastructure in question. These five raw indicators are converted into densities, and this conversion is discussed in greater detail in the next section.

were not chosen and the length of railroad track was selected as the unit of choice for measuring railroad length in this project because it was the most widely available and appropriate.

Number of Automobiles

The invention of the automobile in 1886 set forth a wave that would eventually alter the landscape of transportation systems (Bardou et. al. 1982). Much like railroads, automobiles were not beholden to animal or human power to move people or goods across geographic spaces, making it far easier to move anything and everything and this ease of movement provided fungible benefits to the people utilizing these systems. The automobile introduced one distinct advantage over its railroad counterparts—flexibility. Automobiles are not bound to fixed tracks like railroads, providing an unmatched degree of flexibility when compared to other forms of transportation infrastructure. This flexibility does come at a price in terms of the weight that can be transported using automotive means. Most trucks have maximum limits they can carry before becoming damaged or even crushed by their loads, while the roads and bridges these automobiles drive on can be severely damaged when supporting vehicles that are far too heavy for their construction (Bardou et. al. 1982).

The measure utilized in this project to capture the automotive infrastructure is the number of automobiles within a state in a given year. This measure is the sum total of both automobiles and commercial vehicles within the state during the year in question.

The number of automobiles within a state is intended to serve as a proxy measure for the length of roads within a state.

The length of roads would appear to be a far more intuitive measure of transportation infrastructure and therefore must be carefully considered and discussed. This measure would possess a number of intuitive advantages over the number of automobiles presented above. First, it more directly approximates the railroad measure described above. Comparing the total length of railroad track to the total length of roads would be a more intuitive comparison when contrasted with a measure utilizing the total number of automobiles and the total length of railroad track. Second, the role of roads has been argued to play a significant role in international relations for considerably longer than the temporal domain of this data set or the automobile. One of the explanations given for the longetivity of the Roman Empire was the vast network of roads built throughout this empire, spanning across Europe and into Asia Minor and Northern Africa (Chevallier 1976, Chapter 3; Adams and Lawrence 2001, 1-2). It would appear that road length should be a more suitable measurement for this form of infrastructure.

One primary reason justifies not utilizing the length of roads and moving to a proxy variable for measuring this form of infrastructure. That reason centers on one problem—measurement. Reliable, consistent, cross-nationally comparable data sources and definitions of what constitutes roads are again unavailable for all states in the international system across the time span presented here. One of the only available data sources on roads was from the World Bank, a data set on development that covered a sample of states from 1963 until 1989 (Cropper and Kopits 2003). Within this data sample, however, it was possible to make a statistical comparison between the number of automobiles within a state and the length of roads within in a state. If there is a very high correlation between the number of automobiles and the length of roads, then it would appear that the number of automobiles would function rather well as a proxy for road infrastructure. Fortunately, the correlation between these two measures was extremely high (0.934), providing fairly compelling evidence that the number of automobiles is serving as a fairly accurate proxy for the length of roads within a state.[2]

Air Travel Passenger Kilometers

The Wright Brothers first powered flight at Kitty Hawk, North Carolina, ushered in a new era of transportation infrastructure. Air travel infrastructure possessed one distinct advantage over railroads and automobiles—its speeds. While traveling across the United States was possible by either automobile or train, these journeys could take several days to complete. A current flight from New York to Los Angeles takes only five hours. In addition, trans-continental flights were possible, connecting the world through this form of transportation infrastructure. Air travel infrastructure possesses two limitations, however. The first is that it does possess weight limits when compared to railroad infrastructure. There is only so much weight that can be loaded onto an aircraft

---

[2] The data sets contained 1,662 observations of both the number of automobiles and the length of roadways during this time period for this comparison. While this is a sample of states, this rather large number of observations lends some reliability for this correlation. It is also important to note that this correlation was between total number of automobiles and total road length. The World Bank data contain a number of different measures for road lengths, and for publication it would be useful to show all the very high correlations in order to demonstrate more prominently the robustness of this correlation.

and successfully flown someplace. The second limitation is that air transport is limited in where it can take off and land, resembling railroad infrastructure much more than it resembles automobile infrastructure (Morris and Smith 1953).

The measurement utilized to capture air travel infrastructure is the passenger-kilometer. High values of this measure indicate an air travel system moving a large number of people across longer distances, while small measures of this indicator signify states that are moving fewer passengers across shorter distances.

Two alternate measures existed for air travel infrastructure that was not utilized for various reasons. The first indicator could have been some measure of the number of airports within a state. A state with a large number of airports would have greater air travel infrastructure than a state with very few airports. A few problems exist when considering the utilization of airports as a unit of measurement. First, not all airports are the same; there are different standards across all the states of the international system. What defines an airport in the United States is an airfield that can land a Boeing 747 or some standard of runway length, while an airport in Kenya may utilize a very different standard. Second, like many other potential indicators, there are not enough data available in order to utilize this measure cross-nationally.

A second alternate measure for air travel infrastructure is air freight kilometers, capturing the ability of a particular state to move goods using their airport facilities. This measure, like so many others, runs into the problem of a lack of available data. While air travel passenger kilometers were available for almost all the states in the international system, freight kilometers of air transport are available for less than half of the states identified in the international system, thereby dramatically reducing the viability of this particular data series (Mitchell 1998).

Communication Infrastructure

This study uses two measures to quantify the amount of communication infrastructure within a state in a given year: the number of telegraphs annually and the number of telephones annually in service.

Number of Telegraphs

Beginning with its invention in 1837, the telegraph dramatically increased the speed of communications across large distances. Prior to that point, information had to be sent by courier or post, which meant it could take days to send and receive even the simplest of messages. The telegraph, however, made it possible to send the same amount of information across great distances in a few minutes. This form of communications would dominate the landscape for approximately eighty years until the telephone was invented and entered wide-spread use after World War One (Oslin 1992; Rowland 1997; Winston 1998).

The number of telegraphs sent in a given year is the measure which captures the amount of telegraph infrastructure for a state. High values of this indicator signify states where a large number of telegraphs are being sent, indicating a high degree of telegraph infrastructure, while low values of this indicator indicate states where there is little or no telegraph traffic being sent and therefore low levels of telegraph infrastructure.

For this indicator, there was only one alternate indicator of telegraph infrastructure data gathered anywhere—the length of telegraph lines within a particular state in a given year.[3] This particular indicator was not chosen because there was a very limited amount of data available. This measurement only existed for a select group of large, Western states from the 1860s until around approximately World War One. With such a high degree of missing data, this data source would not measure most of states in the international system and was therefore unsuitable for use in this project.

Number of Telephones

The invention of the telephone in the 1870s laid the foundation for dramatic revolutions in communications technology in the beginning of the twentieth century. At first, telephone systems were slow to catch on because they were very cumbersome and required a number of operators in order to complete a single call. Starting with the invention of the automated switchboard, this form of communication infrastructure began to explode in size and importance. Telephone systems were more accessible to the general population because they did not require knowledge of Morse code (as did their telegraph counterparts) nor a human operator to connect the telephone calls (Oslin 1992; Rowland 1997; Winston 1998)

[3] Another possible indicator would be the number of telegraph stations in a state in a given year. A large number of telegraph stations would provide ample opportunity to send and receive telegraphs throughout the state. However, there was no available cross-national telegraph station data available as of this writing.

Telephone infrastructure is measured as the number of telephones in service in a state during a particular year. High values of this measure signify a state with a large number of telephones while low values indicate a state with little or no telephone connectivity.

The only alternate measure considered for measuring telephone infrastructure was data on the number of telephone calls placed in a given year. This data fell into similar patterns to those of the telegraph data described above. These data were present before the First World War; however they become unavailable for most states after 1920, making it unsuitable for tracking across the long time frame presented here (Mitchell 1998).

Moving from Raw Indicators to Final Measures

Now that the five raw indicators of infrastructure have been identified, it is desirable to incorporate them into composite indicators of transportation and communication infrastructure. The first step in this process is to convert these five raw indicators into density measures. The second step is to combine them statistically into a single measure of transportation infrastructure and a single measure of communication infrastructure. The discussion of infrastructure density begins next.

Density of Raw Indicators

When dealing with infrastructure, it is important to utilize measures of density (infrastructure per square kilometer) when creating composite indicators. If these measures were to utilize the five raw indicators, then there could be potential biases incorporated into these measures. For instance, Russia (and later the Soviet Union) possesses relatively high amounts of the raw indicators of infrastructure outlined above. However, Russia is the largest state in the international system geographically (Hoyle and Knowles 1998). Once the geographic size of this state is considered, Russia is one of the lesser-connected states in the international system.

To create measures of density for transportation infrastructure, the three raw indicators are all divided by the area of the state (in thousands of square kilometers) in that particular year. Data for state area come from the Territorial Change Data Set collected by the Correlates of War Project (Tir et al, 1998). This variable measures the area of the state in thousands of square kilometers for all states from 1816 until 2000.

There is one important consideration to mention at this time. The area of the state utilized in these calculations is the geographic size of only the home state, and does not include the area of any possession not contiguous to the home state, most often exemplified by colonial holdings and possessions. This is an important distinction to make because of the nature of the five raw indicators of infrastructure presented above. While data within the home state is fairly reliable, data on infrastructure in colonial possessions is sketchy, less reliable, and often unavailable. Therefore, since the raw infrastructure indicators are all based on the home state and not the colonial possessions of the state, it is important that the state area data also reflect this consideration.[4]

Communication infrastructure density is calculated in a slightly different manner than transportation infrastructure. While communication infrastructure shares the importance of sending large amounts of information across large geographic distances, there is also a very strong interpersonal element to communication infrastructure. Therefore, the density of communication infrastructure is comprised of two elements—the size of the state and the size of its population. The population data come from the Correlates of War National Material Capabilities Data Set Version 3.0 (Singer 1987; Singer, Bremer, and Stuckey 1972). The data for population and state area are summed to create a combination where high values indicate states with large geographic areas or populations and small values represent states with small geographic areas and small populations.[5]

The Choice of Factor Analysis

After converting the five raw infrastructure measures into density indicators, the question arises of how to combine them into meaningful measures of transportation and communication infrastructure. There appear to be two possible paths to create these

4 An interesting follow-up project would be to examine infrastructure in colonies, and see what role these systems play in international conflict. Differences in infrastructure in colonial possessions could also lead to more conflict, however the data are unavailable to perform this analysis at this time.

5 A second alternative was available for combining population and area when measuring densities—multiplying the area and population data together. In order to check this relationship, I created another factor score based on multiplication rather than addition, and the correlation between the measures was 0.917, high enough to support the idea that either coding system is suitable for this purpose.

measures. The first path would be to create a world share indicator, analogous to the CINC measure commonly used in quantitative international relations research today. The second path was to perform factor analysis on the data and create a unique measure of transportation and communication infrastructure. My decision between these two choices was to utilize factor analysis, and the paragraphs that follow explain why.

Looking first at the method utilized by the Correlates of War to create a statistical indicator of national capabilities, this measure possesses two general issues that make it unsuitable for use in this milieu. One issue with the CINC method is that it relies on being able to calculate a global percentage for each state on each of the six indicators of state capabilities. While these percentages for each indicator of national capabilities possess a certain degree of face validity, the same would not be said for a world percentage of infrastructures. The problem with this technique lies in the fact that this data deals with densities; world shares of particular commodities make intuitive sense, however world shares of densities possess little intuitive value. Stating "The United States possessed ten percent of the world's military spending in 2000" makes intuitive sense; people can imagine at least in vague terms what ten percent of global military spending would look like. Stating that "the United States possessed five percent of the world's transportation infrastructure density" does not possess the same degree of intuition as the military spending example described above. Therefore, a system of computing measurements that does not rely on world shares would appear to be more suitable when dealing with infrastructure measurements, and factor analysis can provide such a system.

A second issue that arises when discussing the CINC method for generating a composite indicator is weighting. The current system for the CINC measurement system assumes that all six indicators are equally weighted. An increasing world share of total population is the same as increasing a state's world share in military expenditures. This appears to be a somewhat shaky line of argumentation. Most often, capabilities are not linearly or perfectly transferable between forms (Stoll and Ward 1989). Therefore, a system that does not assume a weighting system would appear to be somewhat more useful than the assumed weighting system of the Correlates of War Project. Factor analysis is just such a system.

Factor analysis is a mathematical solution to a theoretical problem. Factor analysis is useful "to represent a set of variables in terms of a smaller number of hypothetical variables" (Kim and Mueller 1978a, 9). Factor analysis examines the statistical commonalities between indicators within a particular data structure, and can identify the number of common statistical indicators that are underlying the measures under analysis and generate a hypothetical measurement that captures those commonalities. These mathematically-constructed factors in and of themselves do not correspond with any concrete, "real-world" phenomena—they are mathematical constructs of the statistical commonalities found in the data series. It is highly incumbent upon the researcher to establish a strong theoretical reasoning and foundation as to why the hypothetical measures produced by factor analysis are an appropriate indicator of their theoretical model (Kim and Mueller 1978a, 9).

Studies in international relations employ this approach. Huth, Bennett and Gelpi utilize factor analysis in their study of militarized interstate dispute initiation between major powers (1992). Their study deals with uncertainty in the international system; however they identify five different indicators that can contribute to uncertainty in the international system. These authors make solid arguments that the number of great powers, the number of alliance clusters, the diffusion of capabilities across states, the diffusion of capabilities across clusters, and cross-cutting alliance ties across clusters all influence uncertainty (1992, 496 – 497). Using factor analysis, they find that there are two factors underlying these five measurements that can represent their theoretical argument (1992, 496 – 498). These authors then make solid theoretical arguments that these two underlying factors represent two forms of uncertainty in the international system for each major power state (uncertainty caused from system size and uncertainty caused from the distribution of capabilities within the system). Using these hypothetical factors in their statistical models, they find that the factor that they argue represented the uncertainty about the distribution of capabilities in the international system does lead major power states to initiate militarized interstate disputes more frequently (Huth, Bennett, and Gelpi 1992, 504).

Factor analysis can provide a similar score for transportation and communication infrastructure in this project. Factor analysis can take the three measured indicators of transportation infrastructure, identify the amount and degree of statistical commonalities within those data series, and produce a hypothetical indicator (or indicators) of transportation infrastructure. Likewise, factor analysis can take the two indicators of communication infrastructure and determine the amount of statistical commonality within those two data series, again producing a hypothetical variable that can be argued represents the communication infrastructure of a country in a particular year.

Factor Analysis Results

With the raw measures identified and the technique for combining them presented, I now perform the factor analysis on the data. When conducting factor analysis, the most important piece of information to examine is the eigenvalues for each factor. This test coefficient is useful to determine whether to retain a particular factor. High eigenvalues indicate a factor should be utilized, while low eigenvalues indicate a factor can be disregarded. One important question to address is what threshold for eigenvalues is suitable for making the distinction between retaining and discarding a factor. Kim and Mueller write: "One of the most popular criteria for addressing the number of factors question is to retain factors with eigenvalues greater than one" (1978b, 43). Therefore, any factor with an eigenvalue greater than one will indicate that a particular factor should be utilized.

For this analysis, I utilize principle component factor analysis, which calculates one factor score for each variable analyzed. It also indicates and calculates a measurement based on these scores that correspond with the number of factors this analysis indicates should be retained.[6]

My expectation for both transportation and communication infrastructure is that they both will have only one factor with an eigenvalue greater than one. Looking first at transportation infrastructure, the factor analysis results appear in Table 3.1 below.

[*Insert Table 3.1 about here.*]

---

[6] Almost all other methods of factor analysis are some derivative of this technique. The specific choice of factor analysis technique does very little to alter the measurements calculated.

These results indicate that there is one underlying factor represented by the three measures of transportation infrastructure (railroad density, automobile density, and air travel density). The eigenvalue for the first transportation factor is 1.824, well over the 1.0 threshold. The eigenvalue for the second factor falls below the 1.0 threshold described above. Therefore, this second factor should not be considered and it appears that these three transportation measures can be utilized to quantify the underlying factor of transportation infrastructure.

With this factor analysis in hand, it was next necessary to rotate the factors. In their initial estimated form, the factors cannot be utilized to create a specific equation or measurement. Rotation manipulates the analysis matrix in order to convert the factors from their initial, raw form, creating an aggregate measure based on the previous analysis (Kim and Mueller 1978, 29-40). After rotating the factors, there was still one last step to perform in order to produce a serviceable measurement of transportation infrastructure. Factor analysis produces measurements that are standardized, with a mean of zero and a standard deviation of one. While the standard deviation is not a cause for concern, the mean of zero is a potential problem in future analyses. For both transportation and communication infrastructure, there are true values of zero for each indicator representing a complete lack of their respective forms of infrastructure. These zero observations are turned into negative standardized values when analyzed and computed using factor analysis. These negative values could make creating meaningful ratios and measurements in future analyses rather difficult. In order to correct this potential problem, the lowest observed value for transportation infrastructure was subtracted from every observation.[7] By adding in this value to the data, the minimum value for transportation infrastructure equals zero instead of an arbitrary negative number, thereby making this measurement easier to interpret. The final equation for calculating transportation infrastructure appears in Equation 3.1 below:

Equation 3.1: Transportation Infrastructure Factor Analysis Equation

$$\text{Transport Inf.} = 0.24008 + (0.16951 \text{ x Railroad Density}) + (0.51904 \text{ x Automobile Density}) + (0.50015 \text{ x Air Travel Density})$$

where:

$$\text{Rail Density} = \left(\frac{\frac{\text{Rail Length (1000 km's)}}{\text{State Area (1000 km}^2)} - 22.02147}{33.59496} \right)$$

$$\text{Automobile Density} = \left(\frac{\frac{\text{\# Automobiles (1000's)}}{\text{State Area (1000 km}^2)} - 5.60536}{28.22726} \right)$$

and

$$\text{Air Travel Density} = \left(\frac{\frac{\text{Air Passenger-Kilometers (1000's)}}{\text{State Area (1000 km}^2)} - 79.91457}{1543.49} \right)$$

These equations are provided in case future researchers want to hand-calculate transportation infrastructure measures for data points not collected in this initial effort. To this end, there are a few things of importance to mention regarding these final equations. First, each of the raw indicators is standardized before performing the factor analysis. Standardization is performed by subtracting the mathematical mean from each measure (22.02147, 5.60536, and 79.91457 for the three raw transportation indicators) and then dividing by the standard deviation of each measure (33.59496, 28.22726, and

---

[7] Subtraction was necessary because the lowest values were always negative, in fact making this an additive function.

1543.49 for the three raw transportation infrastructure measures). Then each of these measures is multiplied by its factor analysis coefficient, and then the minimum observed value for transportation infrastructure is added to each observation. These equations, while complex, make it fully possible to hand-calculate a state's transportation infrastructure should someone choose to take this route.

With this analysis on transportation infrastructure complete, the same process is applied to the communication infrastructure data. The factor analysis results appear in Table 3.2 below.

[*Insert Table 3.2 about here.*]

As with transportation infrastructure, there is only one mathematical factor underlying these two measures of communication, thereby representing a single, unified measurement of communication infrastructure underlying these two data series. The eigenvalue for the first factor is 1.102, over the commonly accepted value of 1.0, while the eigenvalue for the second factor is 0.898, below this same threshold. Therefore, it would appear that there is only one common factor underlying the two measures of communication infrastructure. With this initial analysis performed, these factors are then rotated, converted into a single measure, and the minimum observed value was again added to this measure to make the minimum value equal zero. The final equation for communication infrastructure is depicted in Equation 3.2 below.

Equation 3.2: Communication Infrastructure Factor Analysis Equation

$$\text{Communication Infr.} = 0.72503 + (0.67352 \times \text{Telegraph Den.}) + (0.67352 \times \text{Telephone Den.})$$

where:

$$\text{Telegraph Density} = \left(\frac{\dfrac{\text{\# of Telegraphs (1000's)}}{\text{Area (1000 km}^2\text{) + Population (1000's)}} - 0.0004}{0.00055} \right)$$

and

$$\text{Telephone Density} = \left(\frac{\dfrac{\text{\# Telephones (1000's)}}{\text{Area (1000 km}^2\text{) + Population (1000's)}} - 0.05093}{0.11821} \right)$$

One thing is important to mention about the communication infrastructure measures. By including two elements in the density denominator, area and population, there was a question of how to combine them. Should they be additive as presented here, or should they be multiplicative? The answer to that particular question is simple—it does not matter. The correlations between the measure presented here and using multiplication to generate that density produces a correlation of 0.917, resulting in very little difference in the final empirical results.

Before moving on to begin empirically testing the data generated here, there is a question remaining for which factor analysis techniques can provide an initial answer: is it really necessary to separate transportation infrastructure from communication infrastructure? It is possible that all five indicators presented here are capturing a single underlying idea of broad “infrastructure,” rather than capturing two separate and distinct factors of transportation and communication infrastructure. In order to test this assertion, it was necessary to perform an additional factor analysis estimation. In this third factor analysis model, all five infrastructure density measures were included in the model. If infrastructure is one giant term and can be used freely among many different contexts, then we should expect to see only one underlying factor with an eigenvalue over one when analyzing these five measurements. If the separation and analysis presented here is accurate, then we should see two (and only two) underlying factors emerge. Table 3.3 presents the factor analysis results for this relationship.

[*Insert Table 3.3 about here*.]

The factor analysis results are supportive of the idea that there are two separate, distinct underlying factors in the data. The eigenvalues for factor one and factor two are both above the critical threshold of one, indicating that there are two underlying factors operating within these five measurements. This finding supports the idea that distinguishing between transportation and communication infrastructure is not only a theoretically important idea, but also a statistically important distinction to make. With the factor analysis completed and the data set prepared, it is important to describe the data generated by the factor analysis techniques presented here.

Data Description

With the factor analysis performed on the data, it is now appropriate to give a summary description of the new data set. Table 3.4 provides summary statistics for the new transportation and communication infrastructure data created through this project.

[*Insert Table 3.4 about here*.]

Because of the standardization involved in utilizing factor analysis mentioned above, the standard deviation of one should not be surprising. The minimum values of zero for both indicators indicate that the sliding of the data series worked as planned, providing a scale where zero indicates a state with no infrastructure and avoids counterintuitive negative values on this measure.

Examining the maximum values can prove interesting because these data points identify which states have the highest levels of each infrastructure measure. However, there are two time frames that could be interesting to examine—the highest values of infrastructure throughout the data set and the highest values in the most recent observations (in this case, 1993).

Looking first at transportation infrastructure, Singapore has the highest level of transportation infrastructure in the international system for the entire data set and in the most recent observation. This is clearly due to one consideration—its tiny size. Its raw indicators of infrastructure are not dramatically different from many other states in the international system. Singapore has a very small railway system (with only 39 kilometers of track, while the mean amount in 1993 was 9,214 kilometers of railroads), a fair amount of automobiles (457,000 automobiles, with a global mean in 1993 of 5,185,000 automobiles), and a very large air travel infrastructure system (41,262,000 passenger kilometers, while the global average in 1993 was 15,903,000 passenger-kilometers).[8] However, because Singapore is a very small state at only 683 square kilometers (while the global average state area in 1993 was 716,042 square kilometers), this state is incredibly dense when it comes to transportation infrastructure, thereby justifying its high measurement of transportation infrastructure (Tir et al 1998).

---

[8] This same case could be made for any observation for Singapore throughout this data set.

Looking at communication infrastructure, the state that has the highest levels of infrastructure in the entire data set is not the same as the state with the highest measured infrastructure in 1993.

Historically, New Zealand in 1925 possesses the maximum values in the data set, corresponding with the highest degree of communications infrastructure observed in the international system. This assertion makes little intuitive sense; how can a state possess the highest observed amount of communications infrastructure eighty years ago? New Zealand in 1925 possessed a relatively small geographic size of 268,000 square kilometers, far below the global average of 1,299,757 square kilometers (Tir et al 1998). In addition, New Zealand's relatively small population of 1.258 million when observing these maximum values is also far below the global average of 25 million inhabitants per state.[9] In comparison, New Zealand's telegraph infrastructure carried 16.2 million telegraphs in that one year, while the global average in 1925 was 15.2 million telegraphs in that same year. In 1925, there were 130,000 telephones in service in New Zealand, while the average state in the international system had 511,000 telephones in service (which is a mere 0.16 standard deviations below the global mean). A very average telephone and telegraph infrastructure system, combined with a relatively small population and state area, produced these results.

However, there is a second element that is of interest when examining the communications infrastructure of New Zealand. While this state is the global leader in communication infrastructure, these observations occur shortly after their independence

---

[9] New Zealand's population and area fall more than three standard deviations below these means for both these measures.

in 1920. Over the course of time, New Zealand communication infrastructure trends towards the mean of the international system members rather than maintaining its predominance. This trend takes place because from 1920 until 1993, New Zealand's total population triples in size while their raw indicators of communications infrastructure remain almost constant over that time span. This increase in communications infrastructure density denominators while maintaining almost constant values for the numerators (which are the raw measures of telegraph and telephone data) result in diminishing values for communication infrastructure. These considerations provide evidence that New Zealand's relatively small size and population contributed to its high degree of communications infrastructure and explain its more commonplace standing today.

In 1993, Switzerland possessed the greatest observed amount of communication infrastructure, with a value of 5.237 (which is more than three and a half standard deviations above the global mean of 1.045 in that year). Much like New Zealand, Switzerland possesses average communications assets in 1993. During this year, Switzerland sent 2.043 million telegraphs, while the global average in that year was 4.540 million telegraphs.[10] Likewise, there were 5.975 million telephones in service in Switzerland in 1993, while the global mean was 5.529 million telephones. Much like New Zealand, Switzerland is a relatively small state in geographic area (41,000 square kilometers while the global mean is 716,000 square kilometers in 1993) and also

---

[10] The prevalence of telegraph traffic in 1993 was surprising. Many states in Africa, as well as states that conduct a large amount of international banking, still relied heavily on telegraphs in 1993. When this data set is expanded from 1993 until the present, it will be interesting to observe whether or not the telegraph is in heavy use or if it has been replaced by the Internet.

possesses a small population (6.938 million people while the global mean is 29.559 million people). Again, a state with average raw indicators of communication systems possesses a high level of communication infrastructure due to its relatively small size and population.

Table 3.4 also suggests the data sample collected for this project. This measure was generated for 9,214 national observations from 1840 until 1992. The population for this same period as identified by the Correlates of War Project was 10,888 available observations. This infrastructure data set therefore constitutes coverage of 84.4 percent of all state years within the international system during this time frame. Future expansion of this data set should utilize country-specific archival research as well as interpolation methods described and utilized by other research projects in order to bring this data set up to full national coverage.

One final comment regarding the data is necessary. One often-raised anxiety regarding any data collection is a concern about a lack of data reporting for a variety of reasons, such as the data coming from Africa or from command economies, such as the Soviet Union, China, North Korea, and North Vietnam. While there was a potential for systematic missing data, this problem did not manifest itself during this data collection project. Data for many of these raw indicators are available here because of global institutions that regulate and observe particular infrastructure commodities. For instance, there is the International Civil Aviation Organization and the International Telecommunication Organization, which monitors and regulates three of the infrastructure components presented here. Therefore, while there are missing data values at this time, there does not appear to be an identified systematic missing data problem.

Testing the Data: Does it Appear Reliable?

With these two new measures in place, it is necessary to perform some preliminary assessments of these data in order to determine whether they appear to be accurately modeling infrastructure within states. The first analysis is to examine how these infrastructure measures correlate with other measures utilized in international relations. The second analysis will compare the movement of the two infrastructure measures across time for a single state—Germany. When there is an observable change in the infrastructure data, then there should be an observable historical event that corresponds with the data and vice versa. The third analysis of this new data will examine a single war—the Franco Prussian War of 1870—and evaluate whether the two infrastructure measures presented here can make accurate predictions where other commonly-utilized international relations indicators have failed to make accurate predictions. The fourth analysis will utilize the same methodology as the Franco-Prussian War analysis described earlier; however this test will examine the same sort of relationships outside the European theater by examining the ability of infrastructure to explain outcomes where other indicators have failed for three wars in the Middle East: the 1956 Sinai War, the 1967 Six-Days War, and the 1973 Yom Kippur War. The final analysis of the data will be an evaluation in a more challenging data setting. Data difficulties exist in Africa, where values for many indicators utilized in international relations are often missing. If the data perform as expected in this more difficult milieu, then there would appear to be a fairly solid footing for the data globally. The correlations analysis begins now.

Correlation Analysis

One of the first questions that arise with a new measure is whether that indicator is simply re-measuring some other phenomenon already accounted for. The measures developed here for transportation and communication infrastructure are no exception. A very useful methodological tool to address this question is to perform a correlation analysis on the new measures of transportation and communication infrastructure developed here and several measures that could be mistaken for infrastructure already identified in various literatures.

State wealth is one measurable component that could correlate highly with infrastructure. It is possible that states with high degrees of wealth can afford to build and provide infrastructure, while states that are impoverished cannot afford to spend funds on these systems. Therefore, there could be a positive and high degree of colinearity between state wealth and infrastructure. To test for this possible relationship, I examine the correlation between both infrastructure system measures and the Gross Domestic Product (GDP) of the state in question. My expectation is that there will be some correlation, but not perfect correlation between state wealth and both measures of infrastructure detailed here.

State development is another possible factor where an argument could be made anticipating a high degree of correlation with infrastructure. More developed states would possess greater infrastructure systems, while states that are underdeveloped would not possess high levels of these systems. In order to test the correlation between infrastructure and state development, I utilize three different measures of development.

The first measure I utilize for development is GDP *per capita* (which is not necessarily the same thing as wealth described above). States that have a great degree of wealth relative to their population should possess greater infrastructure systems. The second measure of development I utilize is to examine the energy consumption per capita for each state. States that consume a large amount of energy relative to their population should be in possession of a greater degree of development when compared to states that have smaller amounts of energy consumption per capita.

The third and final measure I utilize for development is a generated variable for development that parallels one utilized in previous research by Stuart Bremer (1992). In his article, he argues that: "A more economically advanced state should be characterized by possessing a share of system-wide economic capability that is greater than its share of system-wide demographic capability" (Bremer 1992, 324-325). This measure of development for each state is quantified by calculating its respective world share of industrial capabilities (primary energy consumption plus iron and steel consumption) divided by the sum total of its world share of demographic capabilities (total population plus urban population). This creates a scale where zero indicates an agrarian society with no industrialization to speak of while higher values indicate a more developed, industrial society. Again, there would be a cause for concern if there was a high degree of correlation between development and both infrastructure measures.

State capabilities are a third area where an argument can be made that measuring infrastructure would be re-capturing another phenomenon. A state with higher national capabilities could potentially have a higher degree of infrastructure, while states with little or no national capabilities may also be devoid of infrastructure systems. In order to examine the colinearity between national capabilities and the two infrastructure systems presented here, I test the correlation between the Correlates of War CINC score for each state and the new composite measures of infrastructure detailed above. Again, a high degree of colinearity between national capabilities and state infrastructure would cast doubt on the face validity of the measures presented here.

The correlation matrix between transportation and communication infrastructure is shown below in Table 3.5. This matrix only covers the time frame from 1950 until 1993 due to severe data limitations on the GDP indicators; however the results support the idea that these two measures of transportation and communication infrastructure are capturing another phenomenon, and not re-measuring state wealth, development, or capabilities.

[*Insert Table 3.5 about here.*]

Overall, the correlation matrix provides some rather interesting insights. For the 3,743 observations available, there is a very low degree of correlation between transportation and communication infrastructure, only being correlated at 0.289. This low degree of correlation again provides some evidence that these forms of infrastructure are relatively independent of each other, and high values for one indicator do not necessarily assume high values for the other. Therefore, the decision to measure them independently again receives some empirical support when examining the correlation between these two measures.

The correlation between state wealth and state infrastructure is rather low as well. The correlation between transportation infrastructure and GDP is 0.108, a very low degree of correlation. In a somewhat interesting finding, there is a far greater degree of correlation between communication infrastructure and state wealth, with those measures being correlated at the 0.477 level. While this degree of correlation is higher than expected, it is not so highly correlated to justify a claim that the communication infrastructure measure presented here is perfectly representing state wealth.

The correlations between the indicators of development and state infrastructure are again lower than expected. The correlation between all three development measures and transportation infrastructure is low across the board. GDP per capita, energy consumption per capita, and the development measure presented above are correlated with transportation infrastructure at 0.194, 0.107, and 0.139, respectively. These correlations are low enough that they are not cause for concern, and also indicate that infrastructure appears to be fairly independent of state development. Looking at the communication side of the scene, the correlations here are somewhat higher than their transportation counterparts, but they are not so high as to be a cause for concern. Communication infrastructure is correlated with GDP per capita at 0.363, with energy consumption per capita at 0.258, and with the development measure at the 0.323 level. These correlations are all within acceptable ranges, and indicate that it appears that a state can possess great levels of development without possessing communication infrastructure. Likewise, a state can possess a great degree of communication infrastructure and perhaps not be developed.

Finally, the correlation between state capabilities (as measured by the Correlates of War CINC score) and the two infrastructure measures is again quite low. Transportation infrastructure is only correlated with the CINC measure by 0.012, almost a non-existent correlation. Communication infrastructure is only slightly more correlated with the CINC score, being correlated by 0.210. This low degree of correlation again provides some evidence that communication and transportation infrastructure variables designed and presented here are not simply rehashed measures of other commonly accepted phenomena.

There is one cause for concern regarding this correlation analysis—the sample size. While 3,743 cases are fairly substantial, it is only forty percent of the 9,214 cases available. This small sample is due to the lack of data for gross domestic product. Therefore, it is useful to examine a larger sample in order to provide more evidence regarding these initial findings. Table 3.6 runs the same correlation analysis omitting the GDP and GDP per capita measures in order to examine a much larger sample of observations.

[*Insert Table 3.6 about here.*]

Comparing across tables 3.5 and Table 3.6, the results are almost identical when examining 8,988 cases (which is 97.5 percent of the infrastructure observations). There is very little difference in correlation coefficients when examining the limited sample discussed at length above and when examining a considerably larger sample. For instance, the correlation between CINC score and transportation infrastructure in the limited sample presented in Table 3.5 was 0.012, while this same correlation was 0.10 in the larger sample. For the correlation between communication infrastructure and energy consumption per capita, the correlation when using 3,743 observations is 0.258, while the same correlation when using 8,988 observations is 0.223. Therefore, it would appear that these correlations are fairly consistent when varying the sample sizes. With these correlation results in hand, it is now important to see if history and these measurements correspond to each other.

Tracking Infrastructure: Germany, 1860 – 1993

While correlations are important, there are additional examinations that can be performed in order to ascertain the face validity of a measure. One such examination is to compare the data and the historical record for a particular state and see whether the data and history follow our expectations. To this purpose, I choose to examine and follow the infrastructure of Germany from 1860 until 1993. During this time frame, there are several events (such as unifications, divisions, and wars) that could have shaped and altered the values for these two indicators, allowing us to examine whether the data appear to be tracking with historical events. Germany during this time fought several wars, as well as both increasing and decreasing in geographic size over that time frame, providing a fair amount of potential variation when examining the infrastructure data for this state. I will first examine transportation infrastructure, then I will examine communication infrastructure. Figure 3.1 below depicts the transportation infrastructure of Germany.

[*Insert Figure 3.1 about here*.]

As expected, the data series begins with a very modest value in 1860. The transportation infrastructure value appears to be rising until 1867, when it suddenly diminishes. This declination of transportation infrastructure corresponds with the several wars of German unification that resulted in the integration and inclusion of Hanover

(1866), Hesse Electoral (1866), Saxony (1867), Hesse Grand Ducal (1867), and Mecklenburg Schwerin (1867) into Germany (Correlates of War Project 2005). Germany almost doubles in area during those two years, from 288,000 square kilometers to 528,000 square kilometers (Tir et al 1998). Assimilating these five states dramatically increased the geographic size of the German state, while none of these five conquered states had measurable transportation infrastructure systems. This increase in geographic area therefore diminished the overall transportation infrastructure of Germany in this time frame, and this decline in transportation infrastructure is observable in the data.

After 1867, the data indicate a slow, gradual increase in German transportation infrastructure. The next observable point of interest in the data series corresponds with 1914, when the First World War begins. During this time frame, there appears to be a mild but observable increase in German infrastructure corresponding closely to the dates of that particular war. It would appear that Germany had to increase its transportation infrastructure in order to tie in their supply lines for the fighting in both France and Russia, thereby necessitating a mild increase in their transportation infrastructure (Tucker 1996). After World War One, the data exhibit a slow, steady increase in German infrastructure until the data series for this state end in 1941 due to the beginning of World War Two.

The transportation infrastructure data resume once East and West Germany re-enter the international system in 1954 and 1955, respectively. At that time, the transportation infrastructure systems of both states appears to be relatively equal. However, as the Cold War progressed, the data indicate that West Germany gained a distinct advantage in transportation infrastructure over its Eastern counterpart. This separation of transportation infrastructure could exist for several potential reasons; however it is possible that the relationship depicted in Figure 3.1 is foreshadowing the findings regarding the role of democracy and infrastructure presented in the next chapter. It is a possibility that the democratic government of West Germany chose to build more transportation infrastructure than their Eastern counterpart. However more rigorous testing of this assertion will have to wait.

By 1990 and reunification, West Germany had approximately twice the transportation infrastructure of East Germany. Once they reunite, we see that there was a small reduction in transportation infrastructure. This drop corresponds to the asymmetric sizes of the two states. West Germany at the time of reunification was 248,000 square kilometers while East Germany was a mere 108,000 square kilometers (Tir et al 1998). Since West Germany was much larger than East Germany, we see a modest drop in transportation infrastructure, but not a perfect averaging of the two states. Finally, the transportation infrastructure data series begins to climb again over the few measured years of a reunified Germany.

With this record of corresponding data values with historical events, it would appear that there is at least some validity in the transportation infrastructure measure developed here. With this support in place, I now examine whether the same can be said for communication infrastructure. Figure 3.2 provides a graphic depiction of Germany's communication infrastructure from 1860 until 1993.

[*Insert Figure 3.2 about here*.]

Early in the data series, a subtly different pattern prevails. The noticeable decrease observed in 1866 and 1867 for transportation infrastructure is not present when examining communication infrastructure. This lack of observable difference can be attributed to the relatively low level of communication infrastructure at that particular time. While there was an increase in the geographic size of Germany, the amount of infrastructure also increased enough to maintain its level of communication infrastructure and not drop in the same way as observed regarding transportation infrastructure.

Over the next fifty years, the data tracks a steady increase in German communication infrastructure, coming to a pinnacle during the First World War. It is during this time that Germany experiences its highest levels of communication infrastructure during this time span before World War Two.

After 1921, the data indicate that German communication infrastructure diminishes over time. The primary reason for this decline in values is that Germany is undergoing an internal communication transition from telegraphs to telephones during this timeframe. In 1919, there were 82.8 million telegraphs sent in Germany. By 1937, only 19.4 million telegraphs were being sent. In contrast, there were 1.7 million telephones in service in 1919, while that number doubles by 1937 with a value of 3.6 million telephones in service in 1937.

German communication infrastructure reaches its lowest values after World War One in 1935 then begins to ascend again over the next five years before again becoming missing due to the Second World War. When the two Germanys re-enter the international system in 1954 and 1955, we see slight differences between the two states in terms of communication infrastructure. West Germany only possesses a slight margin of advantage over its Eastern counterpart. However, in the late 1960s, West Germany begins to separate itself from East Germany in terms of communication infrastructure.

By the time of reunification, West Germany possesses more than a 2:1 advantage over East Germany in terms of communication infrastructure. While there may be a large number of reasons why this relationship may exist, one such explanation may have to do with the differences in regimes of the two states. It is certainly possible that democratic West Germany is developing infrastructure at a greater rate than their East German counterparts. This relationship will be examined in greater detail further along in this project.

Looking at Germany after 1989, there is an observable corresponding decrease in communication infrastructure after reunification, again not being perfectly averaged between the two states. There is also an observable, steady increase in communication infrastructure once they are reunited.

In conclusion, it would appear that the data for both transportation and communication infrastructure plausibly track the historical record for Germany from 1860 until 1993. With this evidence in hand, it is now possible to examine a specific episode during that time frame to see if the data make better predictions than do current measures in international relations. To that end, the next section examines the relative capacities of two states in a time of conflict—the Franco-Prussian War of 1870.

European Conflict and Infrastructure: The Franco-Prussian War, 1870.

With the correlation analysis completed and a discussion of how the infrastructure data track one state's historical record, it is now useful to examine whether the data can make accurate predictions. Data that provide behavioral predictions over other explanations would appear much more useful than data that fail to improve people's understanding of a particular phenomenon. To this end, I will stay in Europe and analyze the Franco-Prussian War between Germany and France in 1870.[11] Germany defeated France in this war (Sarkees 2000).

It is possible that Germany won this war because they possessed greater state capabilities than their French adversaries on all possible dimensions, ranging from military might to transportation and communication infrastructure. In order to examine this relationship, I comparatively examine five indicators of state capabilities: CINC scores; number of military personnel; amount of military expenditures; transportation infrastructure; and communication infrastructure. For each of these five measures, I generate a percentage of each combatant's capabilities for participants in this war by dividing their individual value for a particular indicator by the sum total of that particular indicator for both Germany and France.[12] This re-calculation was necessary because of the very different scales utilized by these very different indicators. CINC is a percentage score, ranging from zero to one, military personnel are measured in thousands of soldiers, military expenditures are measured in millions of British Pounds, while transportation and communication infrastructure are measured in the ways described above. Using percentages of capabilities across all five indicators allows easier, more direct

---

[11] I have performed similar analyses for the onset of World War One and World War Two. The findings for these two wars are similar to these presented here.

[12] It is important to mention that there were three other participants in this war: Baden, Bavaria, and Wurttemberg. These three states were excluded from this analysis for two reasons. First, data was missing for three of these measures (transportation infrastructure, communication infrastructure, and military expenditures) making their inclusion impossible. Second, when compared to Germany and France, these three states all possessed only small amounts of military personnel, making their influence rather limited.

comparisons, and for all five indicators of capabilities to be on the same scale. My expectation is that Germany as the eventual winner of this particular war should have possessed a greater percentage of national capabilities for all five indicators than did France. Figure 3.3 presents a graphic depiction of all five indicators.

[*Insert Figure 3.3 about here.*]

Looking first at the "classic" indicators of national capabilities, it becomes apparent that these indicators are not predicting the outcome of this particular conflict very well. The percentage of capabilities for CINC, military personnel, and military expenditures all indicate that France, and not Germany, possessed more of these commodities than their German adversaries and therefore should have won the Franco-Prussian War. However, looking at the relative levels of transportation and communication infrastructure, these indicators appear to correspond better with the historical record. Germany possessed a greater percentage of capabilities for both transportation and communication infrastructure. Therefore, at least in this particular case, the two infrastructure measures appear to be functioning better as an anticipation of war outcomes than do broad national capability measures, military personnel, or military expenditure measures. This finding again supports the idea that these measures of infrastructure are useful for making predictions and performing various types of analyses.

Middle Eastern Conflict and Infrastructure: 1956, 1967, and 1973

While the German case is certainly compelling, it is possible that the effect of infrastructure may be limited to Europe and not generalizable across other cases in other locales. Therefore, it is useful to examine other cases of international conflict and war where infrastructure can compete as an explanation for the outcome of these conflicts. To this purpose, I reexamine three wars in the Middle East: the Sinai War of 1956 between Israel and Egypt, the 1967 Six Day War between Israel, Egypt, Jordan, and Syria, and the 1973 Yom Kippur War again between Israel, Egypt, Jordan, and Syria.

These three cases were chosen because other authors identified that, in much the same way as the Franco-Prussian case detailed above, common indicators of national capabilities fail to accurately predict the outcome of this particular conflict. In particular, Organski and Kugler examine these wars, finding that GDP measures were poor predictors of the outcomes of these three particular conflicts (1980, 89-94). Their argument was that their measure of political capacity was a superior measure to this particular indicator. I argue that the measure of transportation and communication infrastructure presented here is superior to these basic measures. In order to make a more comparable analysis to Organski and Kugler's analysis, I also include GDP in these calculations.

The Sinai War was fought between Egypt and Israel throughout the Sinai Peninsula starting on October 29th of 1956 (Sarkees 2000). This war lasted a mere nine days, ending on November 6th of that same year. Although France and England were both involved in the war, both these states joined the fighting late, entering the fray on October 31st. In addition, France and England played relatively smaller roles in this war, with England only suffering 22 combat deaths while there were merely 10 combat deaths for the French army. Because of this limited role, the data for France and England are excluded from this analysis. Israel did the predominance of the fighting, being involved in this war from its inception and suffering the most casualties (189 Israeli combat deaths) of the three states on that particular side of the war. The Egyptian army suffered the greatest casualties in this particular war, losing 3000 soldiers in the fighting (Sarkees 2000). In the end, Israel was victorious, defeating the Egyptian army in this particular war.

Figure 3.4 presents the national capabilities of Egypt and Israel during this particular conflict. Looking across the four commonly examined indicators, it is quickly apparent that these measures are not accurately predicting the outcome of this conflict. Egypt has more than eighty percent of the CINC and military expenditures of the combatants and over seventy percent of the gross domestic product. Even in terms of military personnel, there is a discernable advantage for the Egyptian army. By these measures, Egypt should have soundly defeated the Israelis.

[*Insert Figure 3.4 about here.*]

The indicators for both transportation and communication infrastructure, however, paint an entirely different picture. Israel has a clear and distinct advantage in this particular war, possessing more than sixty percent of the transportation infrastructure and more than seventy percent of the communication infrastructure of these two combating states. Of these six indicators, only transportation and communication infrastructure accurately predict the Israeli victory. Therefore, it would appear that these two infrastructure measures are capturing something in the conflict process that previous indicators of national capabilities are not.

In 1967, it was not merely the Egyptians fighting against Israel; it was a coalition of states arrayed against Israel. Jordan and Syria fought alongside the Egyptians in a unified attempt to conquer Israel. However, this war was even shorter than the Sinai War fought only eleven years earlier. This war lasted a mere six days, resulting in a sound defeat for all the states aligned against Israel. The national capability graphs for the six measures are depicted below in Figure 3.5.

[*Insert Figure 3.5 about here.*]

For the Six Day War, it is readily apparent that the commonly held measures of state capabilities are not accurately predicting all the possible outcomes for this particular war. Gross domestic product, CINC scores, and military expenditure figures all indicate the same pattern of problems. These three measures accurately predict that Israel should have defeated Jordan and Syria, but incorrectly predict that Egypt should have defeated Israel due to their vast advantages over Israel in these three measures. The data on military personnel also inaccurately predict the outcome of this war. Both Egypt and Syria have greater proportions of military personnel in this conflict, indicating that Israel should have been defeated by both these states instead of the observed outcome of an Israeli victory. For these four measures of capabilities, they accurately predict the outcome of the Six Day War only fifty-eight percent of the time (seven out of twelve predictions using these data series).

When examining the relationship between transportation and communication infrastructure among these four warring states in 1967, it becomes readily apparent that Israel possessed a distinct advantage over all of its adversaries in terms of infrastructure. Israel had the majority of transportation infrastructure, with the sum total percentages for the three Arab states not equaling the transportation infrastructure of Israel. This predominance is even more pronounced when examining communication infrastructure.

For this particular indicator, Israel possessed more than sixty percent of the total communication infrastructure for the warring states, while none of its adversaries had more than thirteen percent of the total communication infrastructure. These dramatic advantages in infrastructure result in much more accurate predictions of the outcomes of this particular conflict. Transportation and communication accurately predict the outcome of this war, with Israel defeating Egypt, Syria, and Jordan, in every case equating to a one hundred percent accuracy rate for this particular war. This high rate of prediction provides fairly strong evidence that transportation and communication infrastructure play a part in predicting the outcome of conflicts.

The Yom Kippur war of 1973 was another attempt by the Arab states to destroy Israel. Egypt, Jordan, and Syria attacked Israel in an effort to make this goal a reality. But, once again, Israel was victorious.

[*Insert Figure 3.6 about here.*]

The results for 1973 are a mirror image of those presented in Figure 3.5 for the 1967 war. Gross domestic product, CINC, military personnel, and military expenditures only accurately predict this war's outcome in seven out of twelve cases, while the infrastructure measures presented here are a perfect six for six in predicting Israel's victory.

In conclusion, examining these four wars has provided some very useful insights. First, it appears that infrastructure can make accurate predictions regarding which states will be victorious in wartime. While accuracy in four cases is impressive, it is not the full population of cases. Chapter Four addresses this question head on, examining whether including infrastructure in statistical models is a fruitful enterprise across a large number of international war cases. Second, these results point to an interesting future research question examining the competing ideas of political infrastructure (defined in terms of political capacity) versus transportation and communication infrastructure. Organski and Kugler's cases of international war were set in the context that political capacity (what I have replaced with political infrastructure) was an important consideration in understanding which side in a particular conflict won or lost a certain war. However, the results presented here indicate that transportation and communication infrastructure work very well in making those same predictions. It would certainly be important to determine which of these three forms of infrastructure (political, transportation, and communication infrastructure) is playing the greatest role in shaping these war outcomes.

Infrastructure in Africa: A Statistical Comparison for 1990

For a final test of the reliability of this data, it is often advantageous to examine areas where the test is potentially as hard as possible, straining the data to its limits and observing whether the data perform under adverse conditions. Several researchers have identified that one of the most challenging regions to gather data is Africa. For instance, one author writes: "African states are disproportionately *not* included in analyses because data are not equally available for all states" (Lemke 2003, 120). Lemke also identifies that data collected and gathered on African states may be of lower quality than for other states in the international system. If the infrastructure data were to make accurate analyses utilizing only African data, this would further indicate the robustness of this data series.

For this final test of the infrastructure data, I compare the measures generated for transportation and communication infrastructure for several African states with an alternative measure gathered by Herbst in his book on the power of states in Africa (2000).[13] In this book, he examines the relative road densities of sub-Saharan African states. For this test in this data-difficult region, I compare my composite measure of transportation and communication infrastructure to his one-dimensional measure of road density.

My expectations for this analysis are two-fold. First, I expect my composite measure of transportation infrastructure to somewhat correlate with his measure of road density. If both Herbst and I are measuring the same phenomenon, then there should be some correlation between our efforts. However, it may be more important to see whether this correlation is perfect between Herbst's analysis and my measurement of transportation infrastructure. If the correlation is perfect between his measures of road density and my indicators of transportation infrastructure, then there is no informational improvement when using the composite indicator described in this chapter over a one-dimensional measure.[14] My second expectation is that communication infrastructure will be largely uncorrelated with both Herbst's road density measurements and with the transportation infrastructure rankings.

---

[13] As mentioned before, using road density is a perilous endeavor due to cross-national comparability issues that were discussed earlier in this chapter. However, his analysis was readily-available and published, making it appear that it would at least be suitable for the limited testing presented here.

[14] In addition, perfect correlation would provide evidence that the concerns over cross-national comparisons regarding road data may have been unfounded.

Table 3.6 presents three lists of African states, sorted in the order with states possessing the highest levels of infrastructure at the top and states with the lowest degrees of infrastructure at the bottom.

[*Insert Table 3.6 about here.*]

This table confirms my two expectations about infrastructure in Africa. First, there is a high degree of similarity in rankings between Herbst's initial examination and the transportation infrastructure measure presented here. Eight out of ten states appear in the top ten in both the Herbst Road Density Ranking list and in the Transportation Rankings list created by the data of this project. The only two exceptions to this are Guinea and Cameroon, which are in the top ten according to Herbst, but are still numbers twelve and thirteen respectively on the Transportation Rankings list. Likewise, examining the bottom of these two lists of transportation infrastructure produces similar results. Seven out of ten states that Herbst places at the bottom of road density in Africa are also at the bottom of the list of states when measured using the composite transportation infrastructure measure. One final test also provides evidence that there is a fairly strong (but not perfect) association between Herbst's work and the measure of transportation infrastructure described in this chapter: a rank-order correlation. The correlation between the Herbst Road Density Rankings and the Transportation Rankings created using the transportation infrastructure measure is 0.796, indicating a rather high correlation between the Herbst list and the list created using the transportation infrastructure measure in this chapter. It is also worthy to note that the correlation is not perfect, suggesting that there is additional information being provided by using a composite indicator of transportation infrastructure over a simple one-dimensional indicator such as road density.

Moving now to the comparisons between Herbst's Road Density list and the Communication Rankings list of African states, the similarities exhibited regarding comparisons between road density and transportation infrastructure are far more diminish dramatically. When examining the top of the Road Density Rankings and Transportation Rankings lists, eight out of ten states appeared in both lists. For communication infrastructure, there are only four states (Ivory Coast, Ghana, Kenya, and Cameroon) that are in the top ten on both the Road Density Rankings and the Communication Rankings lists. Likewise, there are only three states that appear in the bottom ten of both Herbst's Road Density Ranking list and the Communication Rankings list (Congo, Mozambique, and Chad). There is very little correlation (-0.005) in their rank orderings between Herbst's road density lists and the list generated by communication infrastructure. In addition, there is little correlation between the Transportation Ranking list and the Communication Ranking list. These two lists of states are correlated at the 0.140 level, providing more evidence that transportation and communication infrastructure are separate and relatively independent forms of infrastructure.

Conclusions

This chapter has presented two new measures, one for transportation infrastructure and one for communication infrastructure. Through a wide variety of statistical tests, it would appear that these measures are valid. However, it is now time to take them from small-N case studies and into the realm of large-N statistical analyses.

Chapter Three Tables

Table 3.1: Factor Analysis Results for Transportation Infrastructure

Factor Number	Eigenvalue	Proportion of Factor
1	1.824	0.608
2	0.976	0.325
3	0.201	0.067

Table 3.2: Factor Analysis Results for Communication Infrastructure

Factor Number	Eigenvalue	Proportion of Factor
1	1.102	0.551
2	0.898	0.449

Table 3.3: Factor Analysis Results When Utilizing All Five Indicators of Infrastructure

Factor Number	Eigenvalue	Proportion of Factor
1	2.077	0.415
2	1.424	0.285
3	0.831	0.166
4	0.522	0.104
5	0.146	0.029

Table 3.4: Summary Statistics For Transportation and Communication Infrastructure, 1840 – 1993.

N = 9,214	Mean	Std. Dev.	Minimum	Maximum
Transportation Infrastructure	0.240	1	0	31.704
Communication Infrastructure	0.725	1	0	15.742

Table 3.5: Correlation Matrix for Transportation Infrastructure, Communication Infrastructure, and Several Explanatory Variables, 1950 – 1993**.**

N = 3,743	Transportation Infrastructure	Communication Infrastructure	Gross Domestic Product	Gross Domestic Product Per Capita	Energy Consumption Per Capita	Development
Communication Infrastructure	0.289					
Gross Domestic Product	0.108	0.477				
Gross Domestic Product Per Capita	0.194	0.363	-0.288			
Energy Consumption per Capita	0.107	0.258	0.157	0.447		
Development	0.139	0.323	0.213	0.376	0.851	
CINC Score	0.012	0.210	0.564	-0.252	0.115	0.159

Table 3.6: Correlation Matrix for Transportation Infrastructure, Communication Infrastructure, and Several Explanatory Variables, 1840 – 1993.

N = 8,988	Transportation Infrastructure	Communication Infrastructure	Energy Consumption Per Capita	Development
Communication Infrastructure	0.269			
Energy Consumption per Capita	0.117	0.208		
Development	0.131	0.223	0.837	
CINC Score	0.010	0.105	0.060	0.160

Table 3.7: African Infrastructure Comparisons

Ranking	Herbst Road Density Rankings	Transportation Rankings	Communication Rankings
1	Nigeria	Togo	Ethiopia
2	Ivory Coast	Senegal	Zambia
3	Malawi	Malawi	Ghana
4	Ghana	Kenya	Gabon
5	Guinea	Ivory Coast	Cameroon
6	Kenya	Ghana	Senegal
7	Togo	Benin	Ivory Coast
8	Uganda	Nigeria	Benin
9	Tanzania	Uganda	Kenya
10	Cameroon	Tanzania	Burkina Faso
11	Dem. Rep. of the Congo	Mozambique	Guinea
12	Senegal	Guinea	Somalia
13	Benin	Cameroon	Mauritania
14	Angola	Gabon	Mali
15	Zambia	Congo	Niger
16	Burkina Faso	Angola	Nigeria
17	Central African Republic	Burkina Faso	Sudan
18	Congo	Dem. Rep. of the Congo	Congo
19	Mozambique	Zambia	Angola
20	Chad	Sudan	Togo
21	Gabon	Ethiopia	Mozambique
22	Somalia	Mauritania	Malawi
23	Ethiopia	Mali	Tanzania
24	Mali	Central African Republic	Central African Republic
25	Mauritania	Niger	Uganda
26	Niger	Somalia	Dem. Rep. of the Congo
27	Sudan	Chad	Chad

Note: Rankings at the top of the chart indicate greater amounts of infrastructure density, while lower rankings at the bottom of the chart indicate states with lesser amounts of infrastructure density.

Chapter Three Figures

Figure 3.1

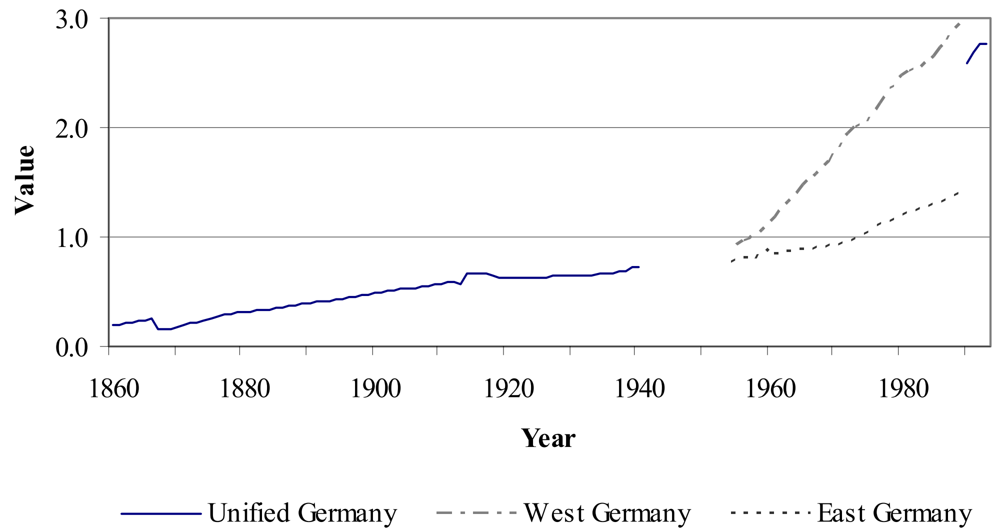

Figure 3.1: German Transportation Infrastructure, 1860 - 1993

Figure 3.2

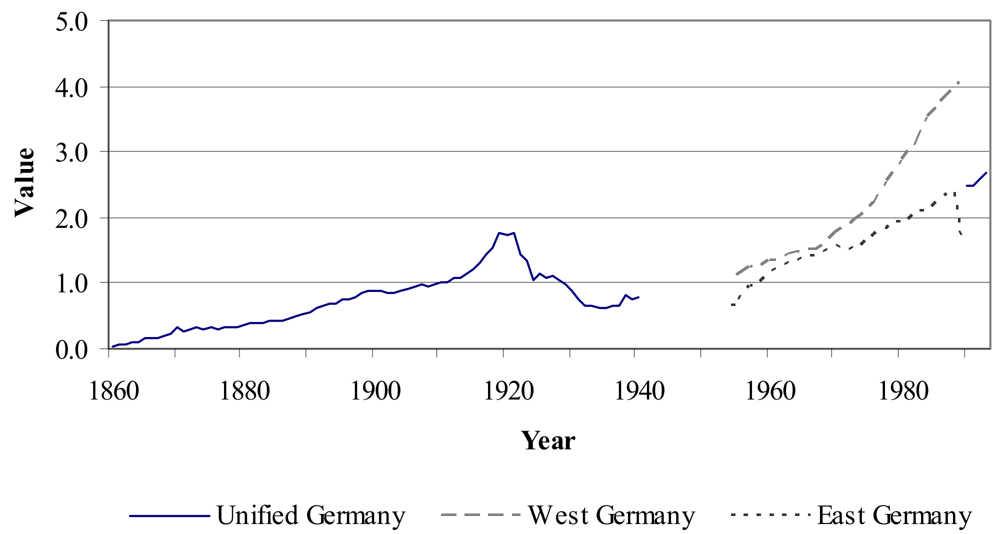

Figure 3.2: German Communication Infrastructure, 1860 – 1993

Figure 3.3

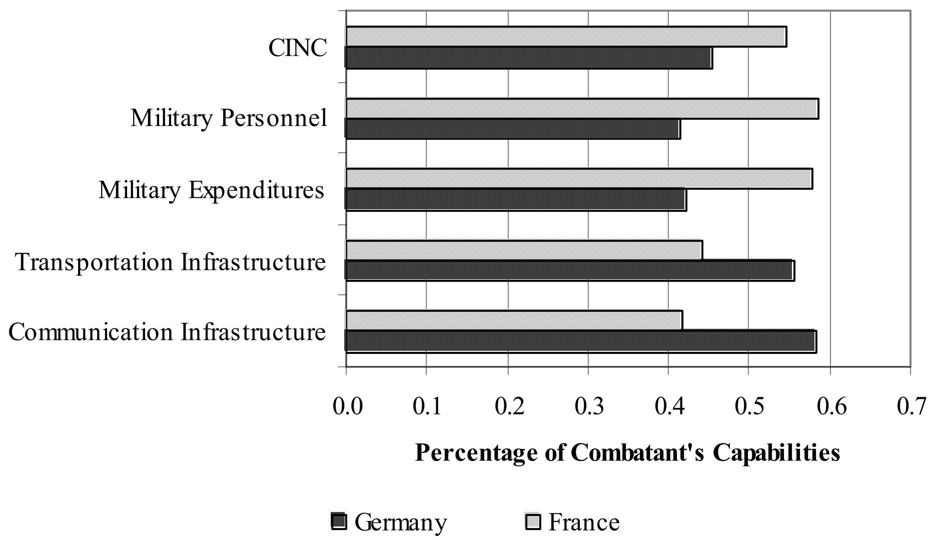

Figure 3.3: National Capabilities of France and Germany During the Franco-Prussian War of 1870

Figure 3.4

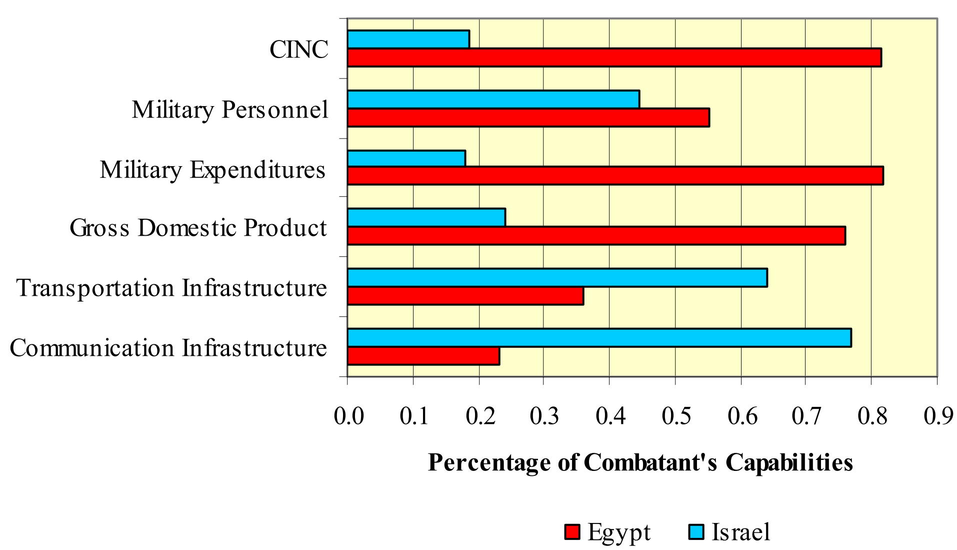

Figure 3.4: National Capabilities of Egypt and Israel During the Sinai War of 1956

Figure 3.5

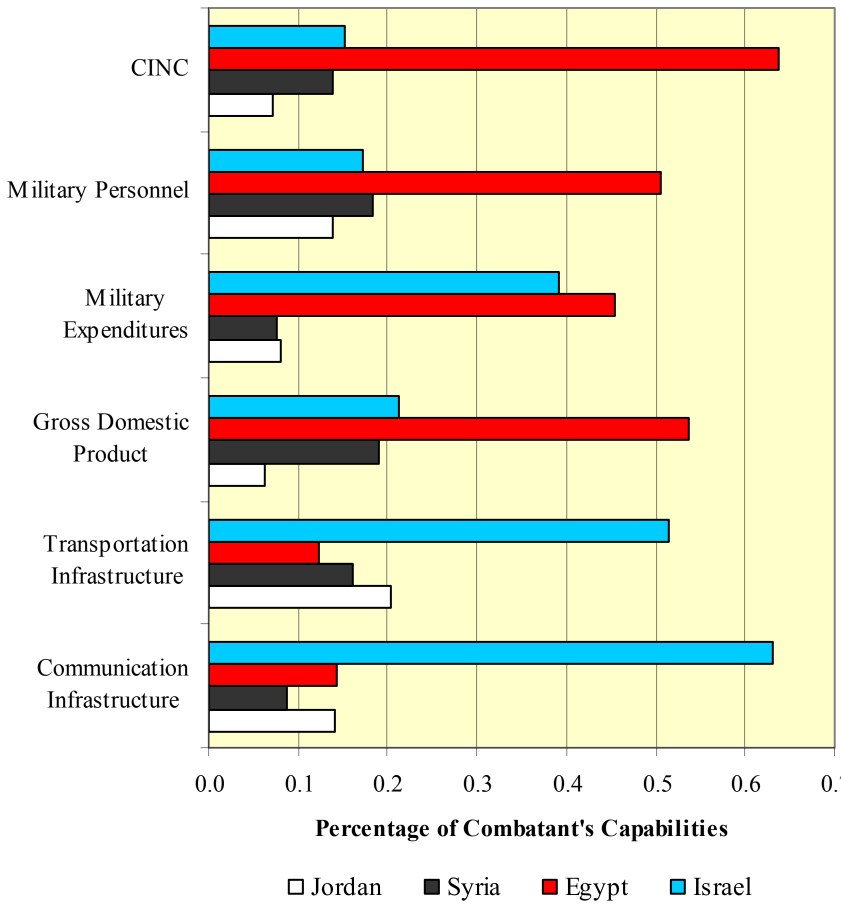

Figure 3.5: National Capabilities of Israel, Egypt, Jordan, and Syria During the Six-Day War of 1967.

Figure 3.6

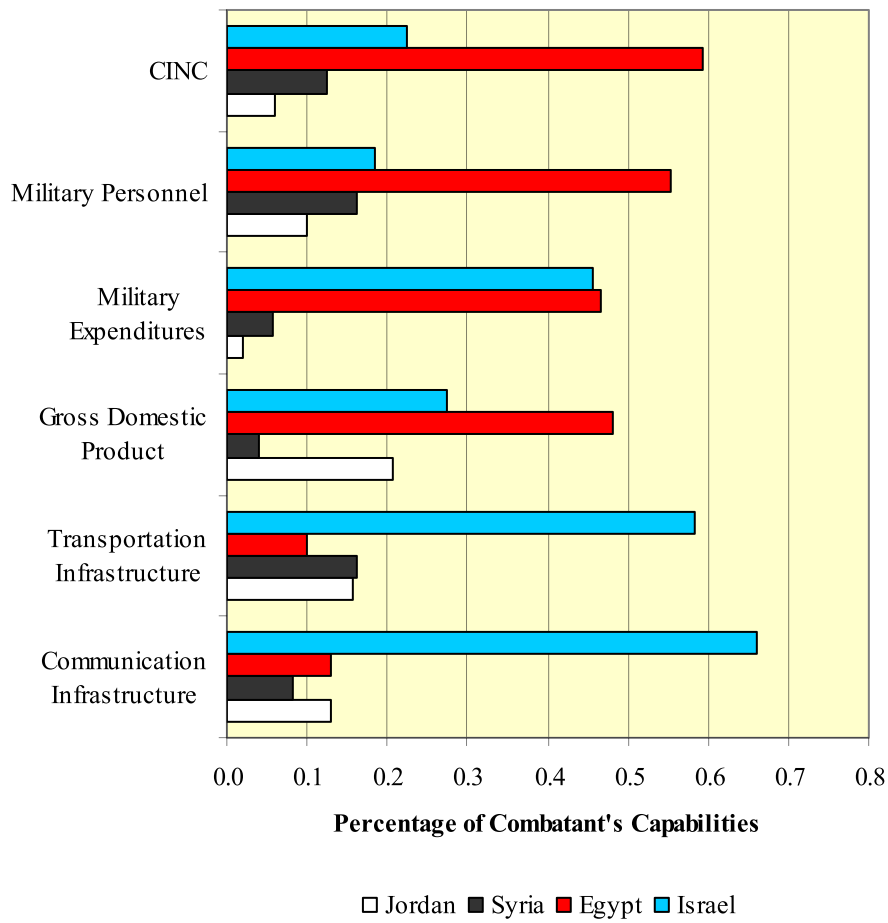

Figure 3.6: National Capabilities of Israel, Egypt, Jordan, and Syria During the Yom Kippur War of 1973.

Chapter 4

The Empirics of War Outcomes

"In war, it is not numbers that give the advantage."

—Sun Tzu

With testable hypotheses established, it is now necessary to test these assertions empirically to provide evidence whether or not these theories hold up under scrutiny. Many things are necessary in order to perform a statistical analysis of war outcomes. It is necessary to identify an appropriate unit of analysis, identify a population of cases, determine the dependent variable, identify and quantify the independent variables, insert statistical control variables, then choose a statistical estimation technique. With these elements of research design in place, I will then present the statistical results, followed by a discussion of the results as well as some caveats about the findings. The discussion of a unit of analysis is the first area of importance, and begins below.

Unit of Analysis

The selection of a unit of analysis can have important implications on a research question. Phenomena can function when utilizing one unit of analysis while they may not operate when studying another unit of analysis. For instance, when examining democracy and its role on interstate conflict, some researchers found that the democratic peace phenomena does not apply when examining the year (Spiro 1992) or the monad as the level of analysis (Maoz and Russett 1993, 624), but when examining dyad-years the democratic peace is "the closest thing we have to a law in international politics" (Levy 1988; Russett 1993). For examining war outcomes, several possible units of analysis are available, and they are each discussed below.

State versus Coalition War Dyad Unit of Analysis

The state versus coalition war dyad is the unit of analysis for this empirical test. There is one observation for each participant involved in a war. In a hypothetical war involving five states, with State A and State B fighting against State C, State D, and State E, there would be five observations and the data would appear as follows:

$State_A$ versus $State_C$, $State_D$, and $State_E$
$State_B$ versus $State_C$, $State_D$, and $State_E$
$State_C$ versus $State_A$ and $State_B$
$State_D$ versus $State_A$ and $State_B$
$State_E$ versus $State_A$ and $State_B$

There are three major lines of justification for choosing this particular unit of analysis. First, individual states are theoretically tied to my hypotheses. The ability to win or lose a war is, at its heart, a phenomenon tied to individual states. The capabilities of the state, when compared to its adversary or opposing coalition, are a suitable approach when considering the outcomes of conflicts. The actions of individual states contribute to their winning or losing wars. While rare, it is possible that some states fighting alongside one another can lose to their opponents while their comrades-in-arms are victorious.[1]

The second justification for this decision is that a previous study of war outcomes utilized this particular unit of analysis (Reiter and Stam 1998). Employing this particular unit of analysis therefore cements the results and findings of this project into the existing literature more concretely than if there were large, wholesale changes to the data structure. The third and final justification for using the state versus coalition war dyad as the unit of analysis is that other potential units of analysis would be unsuitable for analyzing war outcomes, and several of these are briefly described below.

Monadic Unit of Analysis

The monadic unit of analysis is unacceptable for analyzing war outcomes because it omits the characteristics of the state's adversaries. While victory or defeat does lie within the individual state, the capabilities and decisions of the opposing state or opposing coalition are logically part of the conflict process. Utilizing a monadic research design would exclude the characteristics of the opposition and would almost certainly introduce an omitted variable bias into the analysis, casting doubt on any monadic war outcome findings. Therefore, this unit of analysis is not utilized here.

---

[1] The best example of this would be France during World War Two. Being conquered by Germany would certainly constitute a defeat in the short-term, even though England and the United States were eventually victorious and reversed the French defeat a few years later.

Non-Directed Warring Dyad Unit of Analysis

This unit of analysis is common in studies of conflict onset; however it possesses great difficulties in clearly examining war outcomes. Taking into account the factors and capabilities of both sides involved in the war is important (and therefore this unit of analysis is an improvement over the monadic unit of analysis), however the non-directed dyadic unit of analysis cannot differentiate between the two sides of the conflict. Disregarding the sides of the conflict in question does not seem to be an accurate reflection of the conflict process. This unit of analysis could determine the presence or absence of a clear winner, but could not distinguish which of the two sides in each non-directed war dyad had been victorious. Therefore, this unit of analysis is unsuitable and not utilized.

Directed Warring Dyadic Unit of Analysis

The directed state dyad war, examining whether $State_A$ defeated $State_B$ and whether $State_B$ defeated $State_A$, is the final possible but unutilized alternative unit of analysis. While this unit of analysis does have the advantage of introducing the characteristics of both combatants and being able to differentiate the winner of the war (thereby being superior to both the monadic and the non-directed warring dyadic units of analysis), this technique does have a potential issue of inflating the number of observations which can introduce statistical biases.

Using the example described above can illustrate the potential problems with this unit of analysis. If a war is between five states (A, B, C, D, and E), with States A and B on one side of the war, while States C, D, and E are on the opposing side. Using a directed warring-dyad as the unit of analysis would result in having twelve observations, depicted below:

State_A versus State_C	State_C versus State_A
State_A versus State_D	State_C versus State_B
State_A versus State_E	State_D versus State_A
State_B versus State_C	State_D versus State_B
State_B versus State_D	State_E versus State_A
State_B versus State_E	State_E versus State_B

Compare this data structure possessing twelve observations to one using the state versus coalition war dyad as the unit of analysis. The state versus coalition war dyads unit of analysis data series for this hypothetical war would possess five observations as follows:

State_A versus State_C, State_D, and State_E
State_B versus State_C, State_D, and State_E
State_C versus State_A and State_B
State_D versus State_A and State_B
State_E versus State_A and State_B

Utilizing the directed warring state unit of analysis would therefore inflate the number of observations from five to twelve, and this increase in the number of observations would provide greater degrees of freedom and make it easier to reject the null hypotheses and accept the research hypotheses, thereby potentially increasing the possibility of Type I statistical error (Gujarati 1995, 131). By using the state versus coalition war dyad example shown above, there will be far fewer observations in the data set, thereby making it harder to reject hypotheses because of fewer degrees of freedom and smaller deviations in the variables included in the models.[2]

---

[2] It is important to note that for a bilateral war there is no difference between the state – coalition war dyad I utilize and the directed warring dyad unit of analysis discussed here. These observations make up just

Population of Cases

The population of cases for this analysis is all warring states from 1840 until 1993. The original data set ranges from 1816 until 1982 (Reiter and Stam 1998, 383). The changes in temporal domain were necessary for several reasons. The lack of cross-nationally comparable infrastructure data before 1840 made it impossible to reliably track infrastructure prior to that year. This change means a loss of only four observations from the original Reiter and Stam article, making this impact rather small. With infrastructure data available until 1993 and war data available until 2000, it was possible to expand the original data set to include another war—the First Persian Gulf War of 1991. Inclusion of this war added fifteen new observations into the data set, and requires some brief discussion.

For this research, the First Persian Gulf War of 1991 is coded as two separate wars in the data set in the same way that World War One, World War Two, and the Vietnam War were divided in the original data set (Reiter and Stam 1998, 383). The 1991 Persian Gulf War consisted of two distinct periods. The first period was the war between Iraq and Kuwait beginning on August 2, 1990 and lasting only a few days (Sarkees 2000). This first period was a bilateral war between these two states, with Iraq being the victorious side and Kuwait the losing side. The second separate episode in this war was the United Nations coalition of eleven states versus Iraq, beginning on January

---

under half (96 out of 205) of the observations in my data set. The differences in these units of analysis would be most dramatic in large multilateral wars, such as World War One and World War Two.

16, 1991 and concluding on April 11th of that same year. For these twelve observations, the UN coalition was victorious and Iraq was defeated.[3]

Dependent Variable

The dependent variable for this analysis is the outcome of a particular conflict. It takes on a value of one if the warring state won the war and zero if the state in question lost the war. This is the exact same dependent variable Reiter and Stam (1998) utilize, and in order to anchor myself more concretely to their work, I make use of the same dependent variable.

One potential critique of this dependent variable is that wars that ended in a "tie" or "draw" are excluded from this analysis. However, there were only 28 observations that resulted in a tie from the total population of 281 warring state observations from 1840 until 1993. Sixteen of these "tie" observations are stemming from one single war: the Korean War (1950 – 1953). Therefore, "ties" or "draws" of wars are a relative minority and their inclusion or omission should not bias the results presented here.

---

[3] It is important to note that it is possible that when the temporal domain of a previous analysis is changed, that the findings may change. Table 4.5 contains a replication of the original Reiter and Stam (1998) research. My results have some minor changes in the magnitude of the coefficients; however there are no changes in signs or significance levels when altering the temporal domain.

Independent Variables

This section sets forth the quantification of the independent variables in order to quantify and test the hypotheses presented in Chapter Two. Descriptive statistics for the independent variables (as well as all the control variables) are contained in Appendix One at the end of this dissertation.

Transportation Infrastructure

The first hypothesis examines the role of transportation infrastructure on the probability of winning a particular war. This measure is quantified by generating a ratio of transportation infrastructure capabilities between the warring state and its opponent or opponents using Equation 4.1 below:

Equation 4.1: Transportation Infrastructure Ratio Calculation

$$\text{Transportation Infrastructure Ratio}_{A,B} = \frac{\text{Trans. Infra.}_A}{\text{Trans. Infra.}_A + \text{Trans. Infra.}_B}$$

This ratio allows this measure to vary from zero to one. Values of one correspond with a total predominance of transportation infrastructure over an adversary. Values of 0.5 correspond with infrastructure parity or equality; both states have identical levels of infrastructure. Values of zero for this ratio correspond with State_A being at a total disadvantage in transportation infrastructure relative to their adversary. When both states have a transportation infrastructure value of zero, this variable takes on a value of 0.5, thereby assuming that both states are equivalent when neither has a measurable transportation infrastructure system.[4]

When the opponent is a multinational coalition, I utilize the largest infrastructure value for all the states in the coalition. I choose to use this measure because the transportation infrastructure of the largest state will often provide the greatest amount of infrastructure to some composite infrastructure measure generated for a coalition. For example, when coding for the Gulf War of 1991, every state in the UN coalition used Iraq's infrastructure for their opponent, while Iraq used the United States' infrastructure for their measure as the US possessed dramatically better infrastructure than the other UN coalition members.[5]

Utilizing ratios in this way creates three general advantages over using the raw data. First, utilizing ratios converts the infrastructure data into a more readily understood format and data range. Identifying that $State_A$ has a 2:1 infrastructure advantage over $State_B$ is intuitively easier to grasp than stating that $State_A$ has a transportation infrastructure value of 3.2, while its adversary $State_B$ has a transportation infrastructure value of 1.6.

The second advantage of using ratios is that many of the control variables utilized in previous research and this analysis are ratios constructed in the exact same format. By using identical ratio formulas and coding schemes, there is the potential to increase the

---

[4] There are only four cases out of 205 where this assumption is necessary.

[5] Since multilateral wars comprise only half the data set, it is useful to note that differences in coding schemes (such as using some composite indicator of the opposing coalitions) should not make an empirical difference. For instance, changing the coding rules to a composite indicator of infrastructure when coding for the First Persian Gulf War of 1991 would alter the value for only one observation out of fourteen (Iraq against the United Nations Coalition).

correlation between my independent variables of interest and the control variables. This potential increase in correlation could result in an increase in the standard errors surrounding the coefficients in this analysis. This potential increase in standard errors created by using identical ratio formulas could make this statistical test more robust because inflated standard errors make it harder to reject null hypotheses and accept the research hypotheses set forth in Chapter Two.

The third and final advantage of using ratios in this manner is that substantive effects analyses are often more easily understood when all the independent variables are on the same metric. Interpretation can be more difficult when mixing and matching measurement formulas. Post-estimation analysis is somewhat easier when as many variables as possible are on the same metric.[6]

My expectation for the transportation infrastructure ratio coefficient is that it will be positive and statistically significant. The greater the advantage in transportation infrastructure of $State_A$ over its adversary, the greater the likelihood that state will win a war once it has commenced.

Communication Infrastructure

War Outcome Hypothesis Two is quantified in a similar manner as Hypothesis One above. I utilize the raw communication infrastructure data presented in the data section to quantify this term according to Equation 4.2 below:

---

[6] This issue comes up most commonly when attempting to compare continuous variables with dichotomous variables.

Equation 4.2: Communication Infrastructure Ratio Calculation

$$\text{Communication Infrastructure Ratio}_{A,B} = \frac{\text{Comm. Infra.}_A}{\text{Comm. Infra.}_A + \text{Comm. Infra.}_B}$$

All the aforementioned choices and reasoning set forth when discussing transportation infrastructure also apply to communication infrastructure. I expect that this coefficient will be positive and statistically significant, indicating that the greater the relative advantage in communication infrastructure of State_A over its wartime adversary, the greater the probability of that state winning a war once it has commenced.

Transportation Infrastructure and Geographic Proximity

The potential interactive effect between transportation infrastructure and geographic distance is quantified by utilizing a multiplicative interaction term. The variable for this term is created by multiplying the transportation infrastructure ratio described above by the geographic distance from the capital of State_A to the location of the war's battlefields when the war commenced. As an example, this distance measure for the Spanish-American War (which began and was fought almost exclusively in Cuba) equals 7,800 for Spain, while it equals 1,900 for the United States.

My expectation for this variable is that it should be negative and statistically significant; transportation infrastructure should play a greater role in shaping and determining war outcomes when the war is fought closer to the home state, and a diminished role the further away from State_A the war is being fought.

Communication Infrastructure and Geographic Proximity

The potential interactive effect between communication infrastructure and geographic distance is quantified by creating a multiplicative interactive term similar to the one created for transportation infrastructure and geographic distance described above. The variable for this term is generated by multiplying the communication infrastructure ratio described above by the geographic distance from the capital of $State_A$ to the location of the initial battlefields of the war. My expectation for this variable is that it should also be negative and statistically significant; communication infrastructure should play a greater role in shaping and determining war outcomes when the war is fought closer to the home state, and play a lesser role when the war is fought farther away because of the increasing geographic distances involved in fighting the war.

Post-World War One Transportation Infrastructure

This hypothesis deals with the question regarding the relative effectiveness and importance of transportation infrastructure before World War One versus after World War One. To quantify this hypothesis, I start by creating a dichotomous variable that takes on a value of one if the first year of the war is greater than 1925 and zero otherwise. I then multiply this dichotomous variable with the transportation infrastructure ratio described above to create the interaction term.

I chose this particular year because of a natural pause in the data. From 1920 until 1929, there are no observations of war in the data set. With such a long pause, it was possible to utilize any number of potential cut-off points for the pre-and post-World

War One era. Using varying cutoff points from 1919 until 1929 make no statistical difference in the analyses presented here.

My expectation is that transportation infrastructure is less important in the time after World War One than it was in the time up to and including this war. Thus, I anticipate that this variable will be negative, indicating that the overall probabilistic effect of transportation infrastructure diminished in the time frame after World War One. I also expect that this variable will be statistically different from both zero and from the base transportation infrastructure ratio coefficient.

Post-World War One Communication Infrastructure

Hypothesis Six regarding communication infrastructure and war victory after World War One is quantified in the same manner as the post-World War One transportation infrastructure ratio described above. I first create a dichotomous variable that takes on a value of one if the year the war began was greater than 1925 and zero otherwise. I then multiply that dichotomous variable with the communication infrastructure ratio described above. This new interaction term equals zero if the year is less than 1925 and equals the base communication infrastructure ratio variable (again, the one created to test war outcome hypothesis two above) if the year of the observation is greater than 1925.

For this variable, however, I expect that this variable will be positive, indicating that the overall effect of communication infrastructure has become a greater determinant of war victory since World War One. In addition, I also hold that this interactive term will be both statistically different from zero as well as statistically different from the baseline communication infrastructure ratio described above.

Control Variables

While the role of infrastructure is important to examine, there is also the question of what control variables to include in the model. Recent trends in empirical studies have called for a reduction of control variables in statistical models (Ray 2003). For this analysis, I include all the variables utilized in the original Reiter and Stam (1998) article in order to anchor myself to their analysis.[7] All the variables presented here could be correlated to some degree with infrastructure, and not including them could introduce bias into the models.[8]

Geographic Distance

In order to test my hypothesis surrounding geographic distance, it is necessary to include a control variable for the physical space between the warring state and the initial battlefield of the war. This variable is measured in the number of miles from the capital city of the warring state to the physical location of the war. High values indicate long

---

[7] It is important to mention that it is far easier to drop a control variable at a later time if a suitable reason for doing so emerges than it is to begin with a more parsimonious specification which can potentially be rendered statistically insignificant by including originally omitted data.

[8] I have attempted to examine interactive effects between many of the independent variables and several of the control variables discussed here. No significant interactive effects were present and were omitted here for clarity and space. However, there are correlations present; therefore these control variables appear relevant to the study presented here.

distances and wars fought far from $State_A$, while low values indicate much shorter distances from the warring state to the battlefields. My expectation is that the closer a state is to the battlefields of the war, the greater the probability that they will win the war.

Development Ratio

One question that often arises regarding infrastructure is whether or not this measure is simply capturing the development of the warring states. Therefore, it is important to separate out the role that development (or, more directly, differential development) plays in shaping war outcomes. Gross Domestic Product (GDP) per capita and Gross National Product (GNP) per capita are the most popular indicators of development; however data are often unavailable for these two particular measures before 1950. A model using this data from 1950 until 1993 would only contain 49 observations, losing three quarters of my observations.

With this consideration in mind, a proxy variable that would be available across the entire data set was required, and to that end this research utilizes a variable paralleling the one utilized in previous research by Bremer (1992). Bremer argues that: "A more economically advanced state should be characterized by possessing a share of system-wide economic capability that is greater than its share of system-wide demographic capability" (Bremer 1992, 324-325). Differential development for each state is quantified by calculating its respective world share of industrial capabilities (primary energy consumption plus iron and steel consumption) divided by the sum total of its world share of demographic capabilities (total population plus urban population). This creates a scale where zero indicates an agrarian society with no industrialization to speak of while higher values indicate a more developed, industrial society. With this raw measure of development in place, it was then possible to generate a development ratio according to Equation 4.3 below:

Equation 4.3: Development Ratio Equation

$$\text{Development Ratio}_{A,B} = \frac{\text{Development}_A}{\text{Development}_A + \text{Development}_B}$$

Again, this ratio equals one when a state has a total development advantage over an adversary, zero when State_A is completely disadvantaged in terms of development, and 0.5 where the warring states are at developmental parity. This form therefore mimics the one utilized to measure transportation and communication infrastructure, potentially increasing colinearity, inflating standard errors, and possibly making it harder to accept my research hypotheses. My expectation for this variable is that as this ratio increases, the probability that State_A will win the war will increase.

Polynomial Terms

Reiter and Stam (1998) examine the non-linear effects of democracy and initiation on war outcomes. To this end, they create two interactive terms in order to test these theories. Several steps are necessary in order to quantify these two terms. The first step in generating these polynomial terms is to compute a “Regime” score for each state by taking the Polity III DEMOC score and subtracting the AUTOC score (Jaggers and Gurr 1995), generating a variable which ranges from +10 (the most democratic states in the international system) to -10 (the most authoritarian states in the international system).

With this "Regime" measure in hand for each warring state, the second step is to generate a base term variable (denoted as X) using the following equation:

Equation 4.4: Polynomial Base Term Calculation

$$X = \frac{(\text{Regime x Initiation} + 11)}{10}$$

After determining X for each observation, then the final step is to create two curvilinear term variables. Polynomial Term 1 equals $x^{-1/2}$ while Polynomial Term 2 equals $x^{-1/2}$ (ln(x)). The expectation for each of these terms is that they will be negative and statistically significant, indicating that extremely democratic and extremely authoritarian regimes will have increased probabilities of winning wars while states that fall into neither of these categories will have lesser probabilities of winning the wars they become involved in.

Regime-Target Interaction

Reiter and Stam argue that democratic regimes that are the target of wars will win more often that their authoritarian counterparts because of the threat of removal from office, as well as other domestic political consequences not faced by authoritarian leaders. To test this assertion, they create a multiplicative interaction term between regime type and targeting. Regime type is calculated by subtracting the Polity III "AUTOC" values from the "DEMOC" score (Jaggers and Gurr 1995). Then this number is multiplied by a dichotomous variable that takes on a value of one when $State_A$ is the target of the war it is involved in and zero if $State_A$ is the initiator of the war. The expectation for this variable is that this measure will be positive indicating that target states with democratic regimes will win wars more often than authoritarian target states.

Initiation

Research examining rationality and war victory holds that these two phenomena are interrelated. States are more likely to initiate wars that they perceive and calculate to be winnable; therefore initiating states should have a greater likelihood of winning wars (Stam 1996; Wang and Ray 1994; Bueno de Mesquita 1981). This variable is coded as one if $State_A$ initiated the war against their opponent and zero otherwise. The expectation is that this variable will be positive and statistically significant.

Direct Capabilities Ratio

In times of conflict, a state's military strength relative to its adversaries should play an important role in determining whether or not that particular state is successful in winning the war. Therefore, it is important to measure the direct national capabilities of the state when compared to their adversaries in order to control for this alternate explanation of the war's outcome. This variable measures those national capabilities under the direct governmental control of the state, and excludes the capabilities of a state's wartime partners (the states fighting alongside the warring state) which will be captured in another measure.

The direct national capabilities of the warring state versus its adversaries is coded using data from the Correlates of War Project's Composite Indicator of National Capabilities (CINC) data set (Singer 1987; Singer, Bremer, and Stuckey 1972). This variable is measured by dividing the CINC score for $State_A$ by the sum total of all the CINC scores for $State_A$'s opponents in the war plus $State_A$'s own CINC score. This coding scheme allows this variable to range from zero to one; values of zero correspond with $State_A$ having no military capabilities relative to its opponent, values of 0.5 indicating a situation of parity in direct capabilities between $State_A$ and its warring adversaries, and values of one signifying that $State_A$ possesses all the direct national capabilities in that particular war. The expectation for this variable is that as direct national capabilities increase in favor of $State_A$, the greater the probability that $State_A$ will be victorious in war.

Wartime Partners' Capabilities Ratio

The national capabilities of a state's wartime partners are another component of military capabilities controlled for in this analysis.[9] A weak state has a far better chance of victory when fighting alongside powerful comrades-in-arms than if that same weak state had to fight a particular war alone. Reiter and Stam (1998) quantify this variable by taking the sum total of all the CINC scores for all the states that are fighting alongside

---

[9] This measure was originally called "Allies' Capabilities" by Reiter and Stam, however that name is somewhat misleading. This measure captures the national capabilities of the states fighting alongside $State_A$ (hence the name wartime partners), and not the capabilities of the states in a formal alliance (but not necessarily fighting in conjunction) with $State_A$.

(but excluding) $State_A$, and dividing that sum by the sum total of national capabilities (again, as measured by their CINC scores) possessed by *all* the states fighting that particular war (again, excluding the CINC score for $State_A$). Placing the national capabilities of the wartime partners of $State_A$ in both the numerator and the denominator creates a variable which ranges from zero to one in the same manner as direct national capabilities described above. Values of zero indicate that $State_A$ is facing two or more wartime opponents with no help from other states. Values of one signify that $State_A$ is fighting as part of a multinational coalition possessing all the military capabilities in that particular conflict. Values of 0.5 indicate situations where a state's wartime partners have national capabilities equivalent to their combined enemies. In cases of purely bilateral wars (where there would not be wartime partner's capabilities), this variable is assumed to be at parity and takes on the value of 0.5.[10] The expectation for this variable is that it will be positive and statistically significant.

Military Quality

Troop quality is a third control component of the military capabilities of warring states. Several researchers have identified that the better equipped and funded a military force is, the greater the probability that they will be successful on the battlefield (Van Creveld 1991). Therefore, it is important to capture the effects of superior equipment. In order to capture this quality, the most common measure is to calculate the amount of money spent per soldier by their respective government. This measure is quantified by

[10] This is the case for 96 out of the 205 observations in the data set.

taking the military expenditures of a state and dividing by the number of military personnel. The expectation again is that the higher the quality of the military, the greater the probability of victory in war. Therefore, I expect this variable, like those capturing the effects of both direct national capabilities and wartime partner's capabilities, to be positive and significant.

Military Strategy

Previous research has found that military strategy plays an important role in shaping international wars. Particular strategy combinations can make wars longer or shorter in duration (Bennett and Stam 1996), and help states win or lose wars (Reiter and Stam 1998).

In empirical international relations, military strategy has been divided into two dimensions: doctrine and strategy (Levite 1989; Posen 1984; Reiter 1999, 368 – 369). Doctrine is the broad approach to warfare a state takes in order to achieve their political goals during wartime and comes in two forms: offensive or defensive. An offensive doctrine is to attack and take things from an opponent. Using the 1991 Gulf War as an example, the United Nations Coalition fought using an offensive doctrine as they moved to liberate Kuwait from Iraqi occupation. Defensive doctrine, on the other hand, is fighting in order to prevent the other side from achieving their goals. In the aforementioned example, Iraq was fighting a defensive doctrine against the UN coalition in 1991 as they tried to stop the UN coalition from taking back the territory (Kuwait) that the Iraqi army was holding.

Strategy is the method by which the state chooses to fight the war (Reiter and Meek 1999). Strategy comes in three variants, the first being maneuver strategy. This strategy employs speed, driving deep into enemy territory, cutting off troops from their chain of command and their supplies in order to compel them into surrendering. The classic “blitzkrieg” strategies of Germany against the countries of Europe during World War Two, as well as the U.S. invasion of Kuwait and Iraq in 1991 are examples of the maneuver strategy. The second strategy type is an attrition strategy; in this type of warfare, the main purpose and method used by military forces is to meet directly on the battlefield and utterly destroy the opposing army, killing as many enemy soldiers as possible. The trench warfare of World War One or the fighting in the Iran-Iraq war are two examples of attrition-style warfare. The third and final military strategy type is punishment strategy. This strategy attempts to defeat an opponent politically rather than militarily. Instead of directly killing or capturing large numbers of enemy personnel, a punishment strategy utilizes guerrilla-style attacks, including terrorist-style actions, to force an opponent to withdraw from the war. The Viet Cong during the Vietnam War or the current Iraqi insurgent tactics would serve as examples of punishment-style military strategy.

My expectations are that the strategy combination of Maneuver_A, Attrition_B will have a positive and significant coefficient, replicating Reiter and Stam’s original findings. After changing the baseline category, I expect to find a negative and statistically significant coefficient for the Attrition_A, Punishment_B strategy combination. I would expect that when a state on the offensive uses an attrition strategy against a state using a punishment strategy on the defensive (such as the North Vietnamese used against the United States or the Afghani forces used against the Soviet Union), this would decrease the probability of war victory for $State_A$.

Terrain

The role of terrain has been hypothesized and shown to influence international conflict. In clear, open terrain such as a desert, war fighting is easier, making the probability of victory increase. Likewise, in tough, dense terrain, such as the jungles of Vietnam or the mountains of Afghanistan, the probability of winning is much lower due to operational difficulties imposed by the ruggedness of the land.

It is entirely possible that terrain is correlated with infrastructure, making it important to control for this variable. The purpose of infrastructure is to overcome distance; however all distance is not the same. A railroad across a desert makes the trip easier; the same railroad through a dense jungle may be the only way to make the trip at all. Therefore, it appears that controlling for the confounding effects of terrain is important.[11]

The effects of terrain in shaping war outcomes is captured using a continuous variable measuring the difficulties of topography involved in fighting a war in a particular locale. This continuous measure ranges from zero to 0.75, using previously established standards (Dupuy and Dupuy 1986; Dupuy 1983, 1979) that other

---

[11] By this logic, it would appear that there could be an interactive effect between terrain and infrastructure. Because of low number of observation (205), it was impossible to test for this relationship. Future research could examine how terrain and infrastructure interact to influence conflict escalation, where there are approximately 2000 cases, providing statistical leverage for this potentially interesting issue.

international relations scholars also utilized (Bennett and Stam 1996). Zero indicates the most rugged terrain on the planet that a war has been fought in; 0.75 indicates the most open terrain.[12] This is a slight change from Reiter and Stam's original coding scheme. Their scale had values ranging from 0.3 to 1.2; this scale made interpretation difficult because there was no zero value that could be interpreted easily. By sliding the index to include zero, interpretation of their results should be easier.

Strategy-Terrain Interaction

Certain types of military strategies work better in certain types of terrain. A maneuver strategy works far better in an open desert or gently rolling plains than it would if it was used in a dense jungle or steep mountains. Likewise, a punishment strategy would work poorly in the openness of a desert while it could be used very effectively in the aforementioned jungles or mountains. Therefore, I control for the potential interactive effect of military strategy and terrain in the same method set forth by Reiter and Stam (1998).

Statistical Estimation Techniques

For this research, I choose to utilize logistic regression in order to estimate my statistical models. Reiter and Stam (1998) utilize this statistical technique therefore I

---

[12] This variable is the smallest and largest *observed* terrain for warfare. It is possible that there are more open and denser terrains on the planet, but wars have not been fought in these regions.

choose to use the same methodology so my findings are more comparable to theirs. In addition, I also utilize robust standard errors to control for the lack of independence across observations.

In designing any empirical analysis, there are always alternative statistical methods that could be utilized to test hypotheses. There were two potential alternative statistical estimation techniques available: 1) ordered probit or multinomial logistic regression; or 2) logistic regression with losses and ties in the same category. I will briefly discuss why each of these techniques was not utilized.

Estimating an ordered probit or multinomial logit equation that would model the three separate probabilities of a state winning, losing, or fighting to a draw in a particular war is one possible estimation technique. These techniques were not utilized because of the relatively low incidence of "draws" and "ties." There were only 28 cases where draws or ties were observed (comprising only ten percent of the total population), placing a great deal of emphasis on a very limited number of observations.

Estimating a logistic regression with both losses and ties in the same category is the second available alternative for estimating the models presented here. This sort of analysis would put both losing and draws into the same category and estimate a logistic regression model analyzing the difference between being in the "winning" category and the combined "losing" and "tie" categories. This sort of analysis, however, brings up its own set of issues. Placing these two behaviors into the same category would assume they are not just similar, but identical and this seems to be a fallacious idea. The theoretical and behavioral differences between tying a war and losing a war appear to be rather dramatic. Therefore, this statistical technique does not appear to be appropriate and will not be utilized here.

Infrastructure Results

The results presented in this chapter will proceed in two parts. This first section will examine the effects of infrastructure when not including the statistical control variables outlined above. The second section of the empirical results will examine the effects of infrastructure when introducing the statistical controls discussed in previous sections.

My first empirical test of the relationship between infrastructure and victory or defeat in war is to perform a simple examination of differences in mathematical means of both transportation and communication infrastructure and war outcomes. Intuitively, we should expect to see the average transportation and communication infrastructure of winning states to be greater than the mean infrastructure of states that lost wars. This turns out to be the case, as shown in Table 4.1 below.

[Insert Table 4.1 about here.]

Looking first at transportation infrastructure ratios, there is quite a difference between the transportation systems of winning and losing states. Winning states had a mean transportation infrastructure ratio of 0.610, while states that lost wars had a mean transportation infrastructure ratio of 0.314.[13] In more substantive terms states that won

---

[13] One question that often arises is whether or not the mean transportation and communication infrastructure ratio variables should sum to zero. The answer is no. If all wars were bilateral wars, then

wars possessed on average a 3:2 advantage in transportation infrastructure relative to their opponent. Likewise, states that lost wars were on average at a 2:3 disadvantage in transportation infrastructure. This difference in means is also statistically significant ($t = -6.550$, $p < 0.001$), providing some initial evidence that Hypothesis One has some empirical support.

A similar story is painted for communication infrastructure. Winning states possessed a mean communication infrastructure ratio of 0.593, while losing states possessed a mean communication infrastructure ratio of 0.341. This again translates into approximately a 3:2 ratio advantage in communication infrastructure for states that won the wars they fought. Again, this difference in means is statistically significant ($t = -5.777$, $p < 0.001$), lending some support for Hypothesis Two.

With these initial findings in place, it is time to analyze the data utilizing multivariate statistical techniques. The first analyses only examine the three hypotheses regarding transportation infrastructure, for the moment omitting both the control variables and the communication infrastructure variables described above. Several models were estimated, and they are presented in Table 4.2.

[Insert Table 4.2 about here.]

Model One empirically tests Hypothesis One, and does provide some statistical support for this hypothesis. The coefficient for transportation infrastructure is both positive and statistically significant, indicating that as a state gains an advantage in infrastructure over an adversary they improve their probability of winning a war. In an

---

they should sum to zero. But since there can be multiple states with varying infrastructures on either side, it is not necessarily the case that these variables sum to zero.

interesting finding, the variable for geographic distance is negative, indicating that states are more likely to win wars that are farther from their borders. This is counter-intuitive to my hypothesis for this control variable; however this variable is also insignificant, making further interpretation unnecessary.

Model Two in Table 4.2 focuses on testing Hypothesis Two regarding the interactive effects of distance on transportation infrastructure while still controlling for the direct effects set forth in Hypothesis One. The coefficients in this model indicate that there appears to be no interactive effect between transportation infrastructure and geographic distance. The coefficient for the variable introduced in this model interacting geographic distance with transportation infrastructure is negative as hypothesized, however it fails to approach any conventional level of statistical significance. The outcome of a war appears to be the same regardless of the distance from the warring state to the battlefield. When examining changes to both log-likelihoods and pseudo R^2 between Model One and Model Two, it is readily apparent that there is almost no statistical difference between these two models, providing more evidence that there is not a relationship between transportation infrastructure and geographic distance when examining war outcomes. With this evidence in hand, I will not further pursue this hypothesis in this examination.[14]

Model Three in Table 4.2 examines Hypothesis Five regarding the differences in transportation infrastructure between the pre- and post-World War One eras. The statistical results for this hypothesis are encouraging; the coefficient for the Post-World

---

[14] In previous estimations, I have included other variables for this interactive effect. They were never anywhere near statistically significant.

War One transportation infrastructure ratio is negative and statistically significant, indicating that there appears to be a diminished role for these systems after World War One. The coefficients are also statistically different from each other ($t = 12.01$, $p < 0.001$), providing some empirical support for Hypothesis Three.

With these encouraging findings for transportation infrastructure in hand, it is now possible to move on and examine the role of communication infrastructure. The first step in this process is to estimate similar models to those presented earlier, and the results are contained within Table 4.3 below.

[Insert Table 4.3 about here.]

Model Four statistically tests Hypothesis Two, examining the direct effect of communication infrastructure on war outcomes. The results are again encouraging; the coefficient for communication infrastructure ratios is positive and statistically significant, indicating that an increasing advantage in communication infrastructure increases the probability that the warring state will win the war it is fighting. Conversely, when $State_A$ has poor communication infrastructure relative to its opponent, they will lose more often.

Model Five in Table 4.3 examines the interactive effect of distance on infrastructure as described in Hypothesis Four. Again, as in the case of transportation infrastructure, there is no statistical support for this hypothesis. The coefficient for the interactive effect is far from statistically significant. Because geographic distance failed to reach any level of statistical significance in any model, I will not examine it again throughout this chapter.

Model Six in Table 4.3 is the final estimated model for communication infrastructure, and this model examines the difference between the Pre- and Post- World

War One Eras. The coefficient for the overall communication infrastructure ratio remains positive and statistically significant, even after controlling for differences in eras. According to this estimation, the coefficient for the interactive term between the era and communication infrastructure fails to reach statistically significant levels, providing no support at this point for that hypothesis.

The next stage of this analysis is to integrate the findings of both transportation and communication infrastructure into one model. These results are depicted in Table 4.4 below.

[Insert Table 4.4 about here.]

Model Seven in Table 4.4 provides more support for both Hypothesis One and Hypothesis Two. The coefficient for transportation infrastructure ratio is again positive, indicating that states with advantages in transportation infrastructure have higher probabilities of winning the wars they are involved in. Likewise, the coefficient for communication infrastructure is also positive as hypothesized, indicating that the greater the advantage of communication infrastructure over an opponent, the greater the likelihood of that state winning a war against its adversary. Both these coefficients are also statistically significant, making these findings appear rather robust.

Model Eight in Table 4.4 delves into the different eras for both forms of infrastructure under examination. Some unexpected findings emerge from this model when separating out infrastructure during these different eras. Looking first at the coefficients for transportation infrastructure, the findings are rather encouraging. The coefficient for transportation infrastructure is positive and statistically significant, indicating that an advantage over an adversary creates an increase in the probability of winning the war. The coefficient for the interactive term examining transportation infrastructure after World War One is negative and statistically significant, representing a diminished importance of transportation infrastructure after World War One. However, looking at the relative magnitudes of these coefficients, there is a cause for concern. The magnitude of the post-World War One coefficient dramatically increased from Model Three. Previously there was a much smaller coefficient for this variable; in this model, these coefficients are almost identical in size and in opposite directions. Chi squared tests between these coefficients indicate that for the time period after World War One, the net coefficient for transportation infrastructure appears to be effectively zero ($t = 0.54$, $p < 0.46$). While this finding may be somewhat disconcerting, I will hold off on interpreting this result further until after examining the fully-specified models.

Model Eight also produces some interesting relationships regarding the role of communication infrastructure. As in previous models, both coefficients are positive, indicating that advantages in communication infrastructure translate into higher probabilities of winning wars and this effect was greater after World War One. However, the overall communication infrastructure ratio variable is statistically insignificant, while the coefficient for the interactive term examining communication infrastructure after World War One is statistically significant. This finding suggests that communication infrastructure may not have been an important determinant of war victory prior to and including World War One. Only since the technological improvements of the early 1900s has communication infrastructure become an important determinant of winning or losing wars.

Fully-Specified Model Results

With these initial results examining only infrastructure in hand, it is now possible to examine the role of infrastructure when compared to previous empirical findings within the literature. In order to perform this analysis, however, it was helpful to both simplify and modify the model originally published by Reiter and Stam (1998). The simplifications and modifications appear in Table 4.5 below.

[Insert Table 4.5 about here.]

Model Nine in Table 4.5 reprints the original findings as published in their article. Model Ten of Table 4.5 presents a re-estimation of their findings using the 1840 until 1993 time frame in order to ensure that there are no statistical differences when changing the temporal domain of their analysis. The results are not unexpected; all the coefficients possess the same signs and maintain their levels of statistical significance. The only difference between models is that the coefficient for military quality becomes statistically significant. Therefore, it appears that changing the temporal domain of their analysis does not make a significant difference.

After replicating their findings, I made two changes to their statistical model. The first change is to include a control variable for development in order to control for this explanation which competes against infrastructure.

My second change to their original model is to change the omitted category for military strategy. Their analysis distinguished between four categories of military strategy: Maneuver Strategy_A , Attrition Strategy_B; Attrition Strategy_A, Maneuver Strategy_B; Attrition Strategy_A, Attrition Strategy_B; and Punishment Strategy_A, Attrition

$Strategy_B$. When examining their original results, it appears that there is little difference between three of these categories (Attrition $Strategy_A$, Maneuver $Strategy_B$; Attrition $Strategy_A$, Attrition $Strategy_B$; and Punishment $Strategy_A$, Attrition $Strategy_B$) because of their very similar coefficients. Statistical tests confirm this suspicion; there is no statistical difference in the coefficients between Attrition $Strategy_A$, Maneuver $Strategy_B$ and Punishment $Strategy_A$, Attrition $Strategy_B$ ($t = 0.55$, $p = 0.4573$). With that in mind, I turn these three categories into one omitted category and estimate this model with a coefficient for Attrition $Strategy_A$, Punishment $Strategy_B$ (the originally omitted categorical variable) included in my estimations.

Model Eleven in Table 4.5 estimates this model with the modifications in place. There are only a few small differences between the results in this model and those presented earlier. All the coefficients possess the same direction of signs. However, there are a few minor changes to the degrees of statistical significance. The polynomial terms barely fall from conventional levels of statistical significance, while the coefficient for the interaction between regime type and being a target is less significant in this new estimation. These modifications added one more degree of freedom while controlling for another potential explanation of war victory, as well as making their model somewhat simpler to interpret and understand while not degrading its overall explanatory power.

With these modifications completed, the next step in empirically testing these relationships is to estimate a model of war victory and defeat using the variables regarding transportation infrastructure, transportation infrastructure after World War One, communication infrastructure, and communication infrastructure after World War One. The results are depicted in Table 4.6 below.

[Insert Table 4.6 about here.]

Model Eleven in Table 4.6 is a reproduction from Table 4.5, and is included here for simplicity of comparisons between the original models and the new estimations presented here. Model Twelve in Table 4.6 presents the rather dramatic findings when controlling for infrastructure.

First, the coefficient for transportation infrastructure across the whole time span is positive and statistically significant, providing more evidence in support of Hypothesis One. The coefficient for Post-World War One transportation infrastructure is again negative, indicating a relative drop in importance of these systems after 1925. This time, the net difference between the overall ratio and the post-World War One ratio is larger than before, however this difference is again statistically indistinguishable from zero ($t = 1.15$, $p < 0.284$).

The results for communication infrastructure are very similar to the results presented earlier in Table 4.4. The overall effect of communication infrastructure fails to reach any level of statistical significance, but the effect of communication infrastructure after World War One is both positive and statistically significant as hypothesized, indicating that these systems appear to play a vital role in shaping war outcomes after 1925, and thereby providing further empirical support for Hypothesis Six.

For a large number of control variables, there is nothing interesting to report or discuss; advantages in national capabilities, allies' capabilities, military quality, terrain, military strategies, and the strategy-terrain interaction show no change in sign or any substantial change in magnitude when controlling for transportation and communication infrastructure.

However, there are some important and dramatic changes in the remaining control variables. The coefficient for development ratio, the polynomial terms, the regime-target interactive term, and initiation all fail to reach levels of statistical significance after controlling for both transportation and communication infrastructure. Development, the regime-target interaction, and initiation all fall well outside any bounds of statistical significance. The polynomial terms are outside the most generous statistical allowances, but not as far from significance as the development or initiation variables.

In order to strengthen these findings regarding the insignificant coefficients, it is useful to re-estimate a model of war outcomes utilizing only the statistically significant variables. The findings are listed in Model Thirteen in Table 4.6, and no statistical differences appear between Model Thirteen, the simplified model of war outcomes, and Model Twelve, the statistical model containing the previously insignificant variables ($t = 3.40$, $p = 0.7578$).

These empirical findings lead to one common, important, question. Why does infrastructure wash out the effect of these other three measures? The following discussion section will try and shed some light on my findings.

Discussion

My statistical results washed out two components from Reiter and Stam's original analysis—initiation and democracy. In addition, controlling for infrastructure also washed out the statistical results for development. I will first examine initiation then I will examine both development and democracy together.

Initiation

In order to examine and understand this relationship between initiation and infrastructure a useful analysis is to examine if there are differences in mathematical means between initiating states and target states. As argued in Chapter Two and Tested in Chapter Five, it is quite possible that advantages in infrastructure can lead to more aggressive behavior, resulting in increasing dispute and war initiation. These test results are presented in Table 4.7 below.

[Insert Table 4.7 about here.]

These results yield a very interesting result: war initiators have dramatically higher levels of infrastructure than their targets. States that initiated the wars in which they fought had a mean transportation infrastructure ratio of 0.668, which corresponds to a 2:1 infrastructure advantage over their adversaries. Likewise, the states that were the targets of wars possessed an average transportation infrastructure ratio of 0.342, almost equivalent to a 1:2 relative disadvantage in transportation infrastructure. A very similar situation is painted for communication infrastructure. War initiators had an average communication infrastructure ratio of 0.586, which translates into an approximately 1.4:1 advantage while their targets had a mean communication infrastructure ratio of 0.405, which corresponds to a 1.4:1 relative disadvantage. It would appear that there is a rather strong relationship between the initiation of conflict and both forms of infrastructure discussed here. This finding really provides some initial evidence for examining the role of infrastructure on conflict initiation, supporting the need for the hypotheses presented in Chapter Two and tested in the next chapter.

Democracy and Development

Moving now to the question of democracy and development, the initial response from these results would be to declare that democracy plays no role in shaping war outcomes. All the variables associated with democracy were insignificant, and made no statistical difference after being removed from the model after controlling for infrastructure. Likewise, the role of differential development appears to make no difference in who wins and loses wars after controlling for infrastructure.

These assertions may be somewhat premature. Recent empirical research by Bueno de Mesquita and his coauthors finds that states with large selectorates and large winning coalitions (which often are democracies) are more likely to build public works projects in a wide variety of forms: education, health care, social services in various forms, and interstate trade are only a few examples (Bueno de Mesquita et al 2003, Chapter 5). It is quite possible that democratic governments (as well as states that are more developed) choose to build and develop public goods like infrastructure, resulting in higher levels of transportation and communication systems.

In order to test this possible explanation, I begin by performing a statistical analysis on the 205 existing cases in the war outcomes data. My new dependent variable is the amount of infrastructure in these warring states, and I perform two separate analyses for transportation and communication infrastructure. My two independent variables were presented earlier in this chapter and they are the “Regime” measure for

$State_A$ and the development measure of $State_A$.[15] My statistical method changes from logistic regression to OLS regression using robust standard errors and the results of this analysis are listed in Table 4.8 below.

[Insert Table 4.8 about here.]

Model Fourteen depicts the results for transportation infrastructure. The coefficients for both democracy and development are positive and statistically significant, indicating that the more democratic and the more developed a state, the greater the level of transportation infrastructure within that state. The same can be said for communication infrastructure, whose results are shown in Model Fifteen in Table 4.8. Both coefficients are positive and statistically significant, indicating that increased levels of democracy and development lead to increased levels of communication infrastructure. These statistical findings support the aforementioned explanations at least within the limited sample of 205 cases analyzed here: both democracy and development have positive coefficients, indicating that democratic regimes and developed states appear to have higher levels of transportation and communication infrastructure.

However, there is the question of whether or not this is a generalizable finding. While it is interesting that it operates within these 205 cases, it is possible that this relationship only functions within this sample of warring states. In order to address this question of generalizability, I extend the analysis presented in Table 4.8 above to examine all monads in the international system from 1840 until 1993 using the same measures of democracy and development described above. In addition, I introduce two

---

[15] Regime is measured by taking the Polity IV "DEMOC" score and subtracting the Polity IV "AUTOC" score for the warring state. Development is coded in the same was as described earlier in this chapter.

new variables into the model in order to more rigorously test this idea, controlling for both the energy consumption and the iron and steel consumption (both these indicators are logged values) of the state in a given year. My results are presented in Table 4.9 below.

[*Insert Table 4.9 about here.*]

These results again reflect the original findings of the limited domain analysis presented above. For the more than 8500 observations available, democracy is again positive and statistically significant, indicating that more democratic states tend to have higher levels of both transportation and communication infrastructure. The variables for development, energy consumption, and iron and steel consumption, are all positive and statistically significant as well, again indicating that states with higher degrees of development, as well as states with large amounts of energy consumption and iron and steel consumption, tend to have greater levels of both transportation and communication infrastructure, ceteris paribus.

These findings appear to support a change in the story set forth by Reiter and Stam in their original article. In their piece, they argue that democracies are more likely to win their wars for three primary reasons. First, they argue that the militaries of democracies possess advantages because of the domestic political milieu. They assert that: "…democratic armies fight with greater initiative and better leadership than do the armies of other kinds of states" (Reiter and Stam 1998, 378). Second, they argue that democracies select themselves into winnable wars because democratically elected leaders face removal for failing to win wars while their authoritarian counterparts are freer of these constraints. They argue that: "…fear of post defeat political consequences motivates democracies to initiate war only when they are fairly certain of victory" (Reiter and Stam 1998, 378). Finally, they argue that democracies benefit because of better information flows throughout the society, the military, and the government. Because democracies are more open societies, information flows throughout them more freely when compared to the state-controlled information apparatuses of authoritarian regimes. This freedom of information allows democratic states to make more informed decisions, allowing them to select winnable wars more often than their authoritarian counterparts.

The findings of the statistical models presented in Table 4.8 tell and support a different story from the three outlined above. What the results here suggest is that democratic governments are more likely to build transportation and communication infrastructure than their authoritarian counterparts. These infrastructure systems promote a number of benefits, but they also help improve the probability of winning wars if and when they should arise. Therefore, democracy does promote war victory, however democratic forms of government promote victory weeks, months, and years before a war commences when they choose to build infrastructure, and not during the time of the war itself as originally argued by Reiter and Stam.

Substantive Effects and Outcome Predictions

With model estimates complete, there are two important questions remaining. First, how important is infrastructure relative to other explanations of who wins and loses wars? How much of an advantage can infrastructure provide, relative to things like the number of soldiers fighting an opponent? Second, there is the question of how successful the model is in predicting the outcomes. Does this research improve the ability to accurately predict war outcomes?

The substantive effects analyses presented here examine the probabilities of winning a war when comparing the effects of transportation infrastructure and communication infrastructure with direct capabilities and wartime partners' capabilities.[16] In order to examine these substantive effects, it was first necessary to compute a baseline probability of winning a war. For this analysis, I began by setting the military strategy variable equal to its modal category (Attrition Strategy_A, Attrition Strategy_B), terrain to its mean, and calculated the corresponding strategy – terrain interactive term value.

For my first analysis of substantive effects, I examine the pre-World War One Era. In order to model this scenario, I set the values for the Transportation Ratio, Direct Capabilities Ratio, and Wartime Partners' Capabilities Ratio equal to 0.5, indicating parity between the two warring states. I also set the post-World War One transportation ratio and the post-World War One communication ratio variables equal to zero. I then individually varied the transportation ratio, direct capabilities ratio, and wartime partners' capabilities ratio to the value of 0.75. This particular value corresponds with a

---

[16] While other comparisons are available, I choose to focus only on the effects of these variables. My reasoning for ignoring military strategy, terrain, and their interactive effect is because of this interactive effect; in order to paint an accurate picture of any of these four terms, all four must be simultaneously examined, making interpretation difficult. In addition, because the military strategy and terrain variables are all on different scales from both infrastructure measures (dichotomous measures and a continuous measure from zero to 0.75, compared to the zero to one scale of both infrastructure measures), this makes cross-case comparisons difficult. I choose not to discuss the effect of military quality in terms of infrastructure because of their different coding schemes; both infrastructure measures are ratios, while the military quality ratio is a measure of only State_A's military quality, making cross-comparisons tenuous at best.

3:1advantage for all three of these variables.[17] I then calculated the difference in predicted probability for winning given that change in the three independent variables. The results of this variation are depicted in Figure 4.1 below.

[Insert Figure 4.1 about here.]

Looking at this figure yields some interesting comparisons before World War One. Transportation infrastructure plays a fairly significant and important role in shaping war victory during that time frame. Shifting from transportation infrastructure parity to having a 3:1 advantage in transportation infrastructure, results in a corresponding increase of 0.255 in the probability of winning a particular war. A similar shift in direct capabilities ratio results in an increase in the probability of victory by 0.269, an amount very similar to that of transportation infrastructure. Moving from parity to a 3:1 advantage in terms of wartime partners' capabilities yields an increase in the probability of victory by 0.337. It would appear in the time before World War One that transportation infrastructure played a very significant role in promoting victory, being just as important as the number of troops fighting the war and almost as important as the military strength of the states fighting alongside the warring state.

Moving into the contemporary era (the time after World War One), I prepared for this substantive effects analysis by setting the post-World War One Transportation and Post-World War One Communications infrastructure variables equal to 0.5, again creating a baseline probability of war victory. I then varied the measures from 0.5 to 0.75

---

[17] This 3:1 advantage is often referred to in military circles. Therefore, it seemed an appropriate degree of variation. For these three measures presented here, the variation from 0.5 to 0.75 corresponds with less than a one standard deviation change in these variables.

(making sure to vary both transportation variables simultaneously) as I did in the pre-World War One analysis.

In the time after World War One, transportation infrastructure plays a much smaller role in shaping war outcomes. After accounting for the interactive term, moving from transportation infrastructure parity to a 3:1 advantage in transportation systems only yields an increase of 0.069 in the probability of war victory after World War One, only one-third the effect of these systems when compared to their prewar substantive effect. The effect of communication infrastructure plays a larger role than does transportation infrastructure. Shifting from communication infrastructure parity to a 3:1 advantage yields an increase of 0.181 in the probability of war victory, more than double the effect of transportation infrastructure.

These effects of infrastructure in the contemporary era are relatively small when compared to direct capabilities or wartime partners' capabilities. Moving from parity to a 3:1 advantage in terms of direct capabilities yields an increase of 0.319 in the probability of winning a war once it has commenced. Likewise, moving from parity to a 3:1 advantage in terms of wartime partners' capabilities yields a dramatic increase of 0.524 in the probability of winning a war. It appears that transportation an communication infrastructure, wile playing a significant and measurable role, do not play as dramatic a role as direct capabilities or wartime partners' capabilities.

In order to analyze the success or failure in the model's predictive power, it was necessary to first estimate the number of cases correctly predicted by the original Reiter and Stam article. With this in hand, it was then necessary to utilize Model Thirteen and generate a prediction of whether or not $State_A$ would win or lose the war they were fighting. Table 4.10 below presents a comparison of the predictions made by the original model and the updated model discussed throughout this research.

[Insert Table 4.10 about here.]

Looking first at the Reiter and Stam classification grid at the bottom of this table, their model predicts fairly well. It correctly predicted 173 out of the 205 cases available, equating to a 0.844 correct prediction rate. The top half of Table 4.10 shows the prediction rates for the infrastructure models presented in this chapter. This model presented throughout this chapter accurately predicts 177 out of the 205 cases, for a correct prediction rate of 0.863. Overall, this means that the infrastructure model is a four case improvement over the original Reiter and Stam model, which translates into a 0.019 improvement in the probability of correctly predicting the outcome of a particular war.

While this improvement may seem modest, it is important to note that the infrastructure model presented here has some distinct advantages over the original Reiter and Stam article model. First, the infrastructure model requires less information to determine a potential victor for a possible war. The original Reiter and Stam model required data on thirteen different measures in order to make a prediction. The infrastructure model presented here requires data on ten measures. Second, the information necessary to generate a prediction is more available a priori relative to the Reiter and Stam model. Their original model required that the initiator and target be clearly identified in order to quantify many of their measures, however at times it can be difficult to identify an initiator of a war. Since the infrastructure model presented here does not require knowledge of the initiator, it should be easier to utilize this model for a priori prediction.

Correlation Concerns

One potential question that can arise in any statistical analysis is the correlation between key variables. While Chapter Two showed that there are only low levels of correlation between the infrastructure measures and many other measures utilized in international relations, it is possible that when selecting a subset of data (as the statistical analysis in this chapter does) that there could be different correlations from those presented earlier. Table 4.11 presents the correlation matrix between the four statistically significant infrastructure measures and the rest of the variables utilized in the analysis presented in this chapter.

[Insert Table 4.11 about here.]

This analysis yields similar correlation results to those discussed in Chapter Three (the data chapter). The statistical correlation between development and the infrastructure variables is not dangerously high for statistical purposes within this sample of 205 cases. By this matrix, the correlations between the four infrastructure measures and development are 0.51, 0.25, 0.47, and 0.33, below commonly-held levels that would cause critical concern.

A very similar story emerges regarding the correlation between national capabilities and infrastructure. Because the national capabilities ratio is derived from several components that contribute to the construction of infrastructure, such as steel and energy in various forms, the belief would be that infrastructure could highly correlate with the four infrastructure measures. Again, infrastructure correlates far less with national capabilities than originally feared, even though the variables are identically scaled. With correlations of 0.17, 0.06, 0.51, and 0.34, the correlations are present but not as high as anticipated nor so dramatic that they are cause for concern.

Research Caveats

In any research, there are going to be issues that have to be compromised in order to perform the analysis. The findings presented here are no exception, and in the following section I discuss two issues of research design.

One area where this analysis could be improved is to turn this analysis from being time invariant to a time varying model. The models presented here, while very illustrative, examine war outcomes from the point of view of a snapshot a moment before the war begins; it examines how the participants appeared before the war. Many of the variables involved in the model, such as capabilities, strategy, and terrain, could (and often do) vary during the course of a war. A better representation of the wartime process would be to modify infrastructure and other measures at some regular interval as the warring states target and destroy each others militaries, cities, and infrastructure systems. These changes could then show that when a state loses key pieces of infrastructure (indicated by a dramatic drop in their infrastructure measure), their probability of victory should decrease dramatically. This problem is a concern for all models of war outcomes in the literature, and not only for the empirical results presented here. The values for infrastructure, as well as other factors that shape war outcomes (such as troop strengths or military strategies), would be well served through analysis using time varying approaches. Future research should delve into a time-varying approach for examining war outcomes.

A second caveat of this research design is the lack of interaction terms and effects. In the process of thinking about infrastructure, there were a number of potential interactive effects that could have been explored. Infrastructure could have an interactive effect with national capabilities, terrain, military strategy, or regime type. The major problem with interactive effects in this study was not a lack of theory, but a lack of observations to make estimation possible. While some attempts were made to include interactive effects between infrastructure and national capabilities, terrain, military strategy, and regime type into the model, these brief efforts were initially unsuccessful because these interactive terms failed to reach any approximation of statistical significance. Future research should examine these interactive effects more closely, trying to draw out some of these potential relationships.

Conclusions

With this research performed and analyzed, it is always important to summarize what has been learned through this examination. First, there was support for Hypothesis One and Hypothesis Five regarding transportation infrastructure and its post-World War One decline in importance. Transportation infrastructure was an important factor in shaping war outcomes before World War One, but has diminished greatly and only plays a very limited role in shaping these outcomes since the mid 1920s. Second, there was a fair amount of support for Hypothesis Two and strong support for Hypotheses Six. Advantages in relative communication infrastructure do increase the probability of wartime victory; however this relationship only appears to operate in the time period after World War One. Finally, there was no support whatsoever for Hypothesis Three and Four regarding the interactive effects between infrastructure and geographic distance. While geographic distance has been shown to play a significant role in many other milieus, such as conflict onset and conflict escalation, there does not appear to be an interactive effect between distance and infrastructure in shaping outcomes once the war is underway.

The findings presented here also suggest a reformulation of Reiter and Stam's original research findings. Instead of democracies winning wars because of domestic removal from office if defeated, freer-flowing information, and military leaders fighting with greater flexibility, the evidence presented here points to the idea that democratic states tend to build infrastructure more readily than their authoritarian counterparts, thereby enhancing their opportunities to win the wars they fight.

Chapter Four Tables

Table 4.1: Cross-Tabulation of Infrastructure Ratio and War Outcome

Dependent Variable: War Victory By State A

N = 205

	Winning States (# of Obs.)	**Losing States (# of Obs.)**	**Test Statistic (Significance Level)**
Mean Transportation Infrastructure Ratio	0.610 (112)	0.314 (93)	-6.550 ($p < 0.001$)
Mean Communication Infrastructure Ratio	0.593 (112)	0.341 (93)	-5.777 ($p < 0.001$)

Where Infrastructure Ratio Take on the Value When:

1.0 = Total Infrastructure Advantage
0.5 = Infrastructure Parity
0.0 = Total Infrastructure *Dis* advantage

Table 4.2: Logistic Regression Results for Transportation Infrastructure on War Outcomes

Dependent Variable: War Victory By State A	**Model One**	**Model Two**	**Model Three**
$N = 205$	**Coef. (Std. Errors)**	**Coef. (Std. Errors)**	**Coef. (Std. Errors)**
Transportation Infrastructure Ratio $_{A,B}$	2.46154 *	2.72697 *	2.96600 *
	(0.47559)	(0.54197)	(0.59126)
Geographic Distance x Transportation Infrastructure Ratio $_{A,B}$		-0.00026	
		(0.00028)	
Post - World War One Transportation Infrastructure Ratio $_{A,B}$			-1.02325 #
			(0.61439)
Geographic Distance $_{A,B}$	-0.00019	-0.00034	-0.00020
	(0.00011)	(0.00022)	(0.00013)
Constant	1.82855	4.17611	2.01075
	(1.84186)	(3.39880)	(1.95419)
Log-Likelihood	-119.900	-119.392	-118.368
Pseudo R^2	0.151	0.155	0.162

Notes: * Sig. $p < 0.05$ # Sig. $p < 0.10$ Robust standard errors are reported in parentheses.
All significance tests are two-tailed in this analysis.

Table 4.3: Logistic Regression Results for Communication Infrastructure on War Outcomes

Dependent Variable: War Victory By State A	**Model Four**	**Model Five**	**Model Six**
N = 205	**Coef. (Std. Errors)**	**Coef. (Std. Errors)**	**Coef. (Std. Errors)**
Communication Infrastructure Ratio $_{A,B}$	2.19171 *	1.85556 *	2.03413 *
	(0.52907)	(0.66244)	(0.59905)
Geographic Distance x Communication Infrastructure Ratio $_{A,B}$		0.00045	
		(0.00057)	
Post - World War One Communication Infrastructure Ratio $_{A,B}$			0.34387
			(0.55517)
Geographic Distance $_{A,B}$	-0.00014	0.00013	-0.00014
	(0.00010)	(0.00026)	(0.00010)
Constant	1.28864	-2.93495	1.23326
	(1.59243)	(4.03189)	(1.57619)
Log-Likelihood	-124.543	-123.640	-124.360
Pseudo R^2	0.118	0.124	0.119

Notes: * Sig. $p < 0.05$ # Sig. $p < 0.10$ Robust standard errors are reported in parentheses.
All significance tests are two-tailed in this analysis.

Table 4.4: Logistic Regression Results for Both Transportation and Communication Infrastructure on War Outcomes

Dependent Variable: War Victory By State A	**Model Seven**	**Model Eight**
N = 205	**Coef. (Std. Errors)**	**Coef. (Std. Errors)**
Transportation Infrastructure Ratio $_{A,B}$	2.20654 *	3.30989 *
	(0.50194)	(0.65537)
Post-World War One Transportation Infrastructure Ratio $_{A,B}$		-2.76928 *
		(0.88920)
Communication Infrastructure Ratio $_{A,B}$	1.82658 *	0.87923
	(0.54926)	(0.64978)
Post-World War One Communication Infrastructure Ratio $_{A,B}$		2.26253 *
		(0.87755)
Geographic Distance $_{A,B}$	-0.00010	-0.00008
	(0.0001)	(0.00010)
Constant	-0.21017	-0.46775
	(1.60483)	(1.59364)
Log-Likelihood	-113.910	-108.764
Pseudo R^2	0.193	0.230

Notes: * Sig. $p < 0.05$ Robust standard errors are reported in parentheses.
All significance tests are two-tailed in this analysis.

Table 4.5: Logistic Regression Results for Temporal Domain, Military Strategy, and Development Modifications

Dependent Variable: War Victory By State A $N = 205$	**Model Nine** Coef. (Std. Errors)	**Model Ten** Coef. (Std. Errors)	**Model Eleven** Coef. (Std. Errors)
Development Ratio $_A$			1.939 ** (0.936)
Regime $_A$ x Initiation $_A$ (Polynomial Term 1)	-3.670 * (1.980)	-5.576 * (3.453)	-3.837 (3.451)
Regime $_A$ x Initiation $_A$ (Polynomial Term 2)	-1.070 * (0.600)	-1.600 * (1.068)	-1.061 (1.068)
Regime $_A$ x Target $_A$	0.064 ** (0.030)	0.094 ** (0.056)	0.083 * (0.056)
Initiation $_{A\ against\ B}$	0.960 ** (0.350)	1.856 ** (0.713)	1.584 ** (0.738)
Direct Capabilities Ratio $_{A,B}$	3.760 ** (0.530)	6.115 ** (0.957)	5.492 ** (1.036)
Wartime Partners' Capabilities Ratio $_{A,B}$	4.710 ** (0.680)	8.051 ** (1.336)	8.042 ** (1.425)
Military Quality $_A$	0.051 (0.030)	0.100 ** (0.039)	0.090 ** (0.039)
Maneuver Strategy $_A$, Attrition Strategy $_B$	7.620 ** (2.930)	15.934 ** (6.339)	7.164 ** (2.796)
Attrition Strategy $_A$, Maneuver Strategy $_B$	3.760 * (2.020)	8.264 ** (4.110)	
Attrition Strategy $_A$, Attrition Strategy $_B$	3.570 * (1.450)	7.391 ** (3.188)	
Punishment Strategy $_A$, Attrition Strategy $_B$	3.210 * (1.260)	6.100 ** (3.157)	
Attrition Strategy $_A$, Punishment Strategy $_B$			-6.129 ** (2.643)
Terrain	-11.310 ** (3.020)	-22.272 ** (6.301)	-19.126 ** (5.085)
Strategy-Terrain Interaction	3.680 ** (0.990)	7.250 ** (2.052)	6.236 ** (1.591)
Constant	-2.140 (2.490)	-12.307 ** (6.529)	-6.323 * (4.031)
Log Likelihood	-64.900	-64.011	-61.737
Pseudo R^2	0.520	0.547	0.563

Notes: ** Sig. $p < 0.05$ * Sig. $p < 0.10$ Robust standard errors are reported in parentheses.
All significance tests are one-tailed, as in the original Reiter and Stam article.

Table 4.6: Logistic Regression Model Results for Transportation and Communication Infrastructure on War Outcomes, Controlling for Reiter and Stam's Research Findings

Dependent Variable: War Victory By State A *N* = 205	**Model Eleven** **Coef.** **(Std. Errors)**	**Model Twelve** **Coef.** **(Std. Errors)**	**Model Thirteen** **Coef.** **(Std. Errors)**
Transportation Infrastructure Ratio $_{A,B}$		6.196 ** (1.671)	5.599 ** (0.900)
Post-World War One Transportation Infrastructure Ratio $_{A,B}$		-4.571 ** (1.585)	-3.937 ** (1.588)
Communication Infrastructure Ratio $_{A,B}$		-0.707 (0.920)	
Post-World War One Communication Infrastructure Ratio $_{A,B}$		4.659 ** (1.585)	3.801 ** (1.412)
Development Ratio $_{A,B}$	1.939 ** (0.936)	-0.609 (1.230)	
Regime $_A$ x Initiation $_A$ (Polynomial Term 1)	-3.837 (3.451)	-4.971 (3.380)	
Regime $_A$ x Initiation $_A$ (Polynomial Term 2)	-1.061 (1.068)	-1.413 (1.087)	
Regime $_A$ x Target $_A$	0.083 * (0.056)	0.060 (0.057)	
Initiation $_{A\ against\ B}$	1.584 ** (0.738)	-0.168 (0.842)	
Direct Capabilities Ratio $_{A,B}$	5.492 ** (1.036)	7.223 ** (1.628)	6.076 ** (1.211)
Wartime Partners' Capabilities Ratio $_{A,B}$	8.042 ** (1.425)	10.028 ** (1.483)	9.559 ** (1.369)
Military Quality $_A$	0.090 ** (0.039)	0.074 ** (0.025)	0.068 ** (0.024)
Maneuver Strategy $_A$, Attrition Strategy $_B$	7.164 ** (2.796)	7.365 ** (2.823)	7.612 ** (3.229)
Attrition Strategy $_A$, Punishment Strategy $_B$	-6.129 ** (2.643)	-6.042 ** (2.971)	-6.750 * (3.490)
Terrain	-19.126 ** (5.085)	-21.724 ** (5.122)	-21.925 ** (5.782)
Strategy-Terrain Interaction	6.236 ** (1.591)	6.926 ** (1.690)	7.024 ** (1.919)
Constant	-6.323 * (4.031)	-7.157 * (3.873)	-12.227 ** (2.355)
Log-Likelihood	-61.737	-50.943	-52.641
Pseudo R^2	0.563	0.639	0.627

Notes: ** Sig. $p < 0.05$ * Sig. $p < 0.10$ Robust standard errors are listed in parentheses.
All significance tests are two-tailed in this analysis.

Table 4.7: Cross-Tabulation of Infrastructure Ratio and War Initiators

Dependent Variable: War Initiation By State A
N = 205

	Initiating States (# of Obs.)	**Target States (# of Obs.)**	**Test Statistic (Significance Level)**
Mean Transportation Infrastructure Ratio	0.668 (84)	0.342 (121)	-7.295 ($p < 0.001$)
Mean Communication Infrastructure Ratio	0.586 (84)	0.405 (121)	-3.932 ($p < 0.001$)

Where Infrastructure Ratio Takes on the Value When:
1.0 = Total Infrastructure Advantage
0.5 = Infrastructure Parity
0.0 = Total Infrastructure *Dis* advantage

Table 4.8: OLS Regression Results for Democracy and Development Using Reiter and Stam's Observations, 1840 - 1993

	Model Fourteen	**Model Fifteen**
Dependent Variable	**Transportation Infrastructure $_A$**	**Communication Infrastructure $_A$**
	Coef. (Std. Errors)	**Coef. (Std. Errors)**
Democracy $_A$	0.013 *	0.051 *
	(0.005)	(0.017)
Development $_A$	0.097 *	0.454 *
	(0.027)	(0.175)
Constant	0.141 *	0.365 *
	(0.028)	(0.100)
R-Squared	0.2003	0.2363
N	205	205

Notes: * $p < 0.01$ Robust standard errors are listed in this table.
All significance tests are two-tailed.

Table 4.9: OLS Regression Results for Democracy and Development Using All Available Monads, 1840 – 1993.

	Model Sixteen	**Model Seventeen**
Dependent Variable	**Transportation Infrastructure $_A$**	**Communication Infrastructure $_A$**
	Coef. (Std. Errors)	**Coef. (Std. Errors)**
Democracy $_A$	0.012 *	0.013 *
	(0.001)	(0.001)
Development $_A$	0.048 *	0.007 *
	(0.009)	(0.004)
Logged Energy Consumption $_A$	0.012 *	0.024 *
	(0.003)	(0.002)
Logged Iron and Steel Consumption $_A$	0.020 *	0.121 *
	(0.005)	(0.004)
Constant	0.068 *	-0.189 *
	(0.011)	(0.013)
R-Squared	0.0411	0.2908
N	8,502	8,502

Notes: * $p < 0.01$ Robust standard errors are listed in this table.
All significance tests are two-tailed.

Table 4.10: War Outcome Prediction Matrices

Infrastructure Model Classification

		Estimated	
		Win	Lose
Observed	Win	78	15
	Lose	13	99

Original Reiter and Stam Classification

		Estimated	
		Win	Lose
Observed	Win	76	17
	Lose	15	97

Table 4.11: Correlation Matrix of Infrastructure and Explanatory Variables

N = 205	Transportation Infrastructure Ratio $_{A,B}$	Post-World War One Transportation Infrastructure Ratio $_{A,B}$	Communication Infrastructure Ratio $_{A,B}$	Post-World War One Communication Infrastructure Ratio $_{A,B}$
Post-World War One Transportation Infrastructure Ratio $_{A,B}$	0.44			
Communication Infrastructure Ratio $_{A,B}$	0.34	0.21		
Post-World War One Communication Infrastructure Ratio $_{A,B}$	0.20	0.73	0.50	
Development Ratio $_{A,B}$	0.51	0.25	0.47	0.33
Regime $_A$ x Initiation $_A$ (Polynomial Term 1)	0.07	0.13	0.14	0.23
Regime $_A$ x Initiation $_A$ (Polynomial Term 2)	-0.09	-0.13	-0.15	-0.22
Regime $_A$ x Target $_A$	0.32	0.25	0.14	0.16
Initiation $_{A\ against\ B}$	0.46	0.09	0.27	0.13
Direct Capabilities Ratio $_{A,B}$	0.17	0.06	0.51	0.34
Wartime Partner's Capabilities Ratio $_{A,B}$	0.04	-0.03	-0.04	-0.08
Military Quality $_A$	0.18	0.18	0.30	0.21
Maneuver Strategy $_A$, Attrition Strategy $_B$	0.03	0.21	0.02	0.19
Attrition Strategy $_A$, Punishment Strategy $_B$	-0.14	0.01	-0.11	0.05
Terrain	0.18	0.48	0.22	0.50
Strategy-Terrain Interaction	0.15	0.33	0.13	0.30

Chapter Four Figures

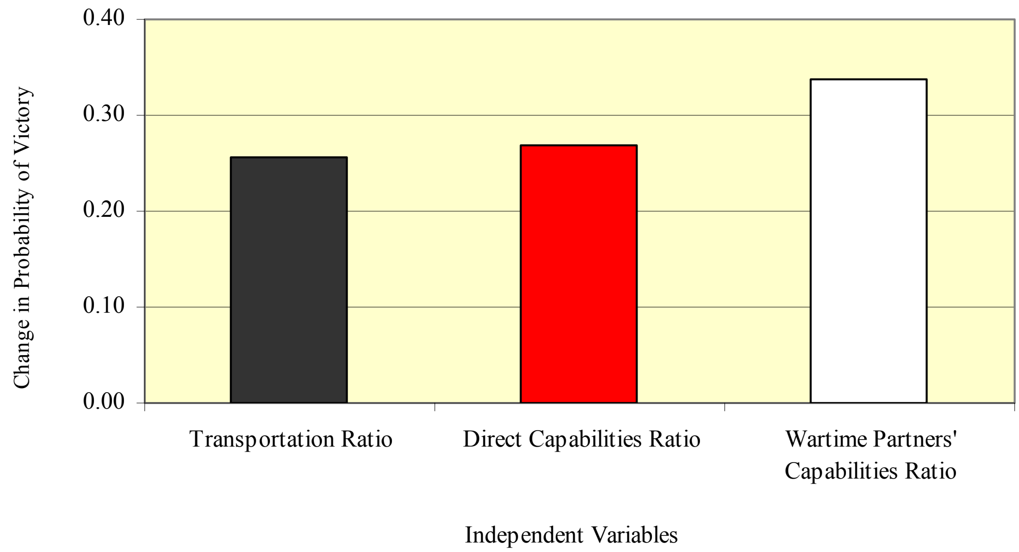

Figure 4.1: Pre-World War One Substantive Effects on the Probability of War Victory: Changing from Parity to a 3:1 Advantage in Key Explanatory Variables

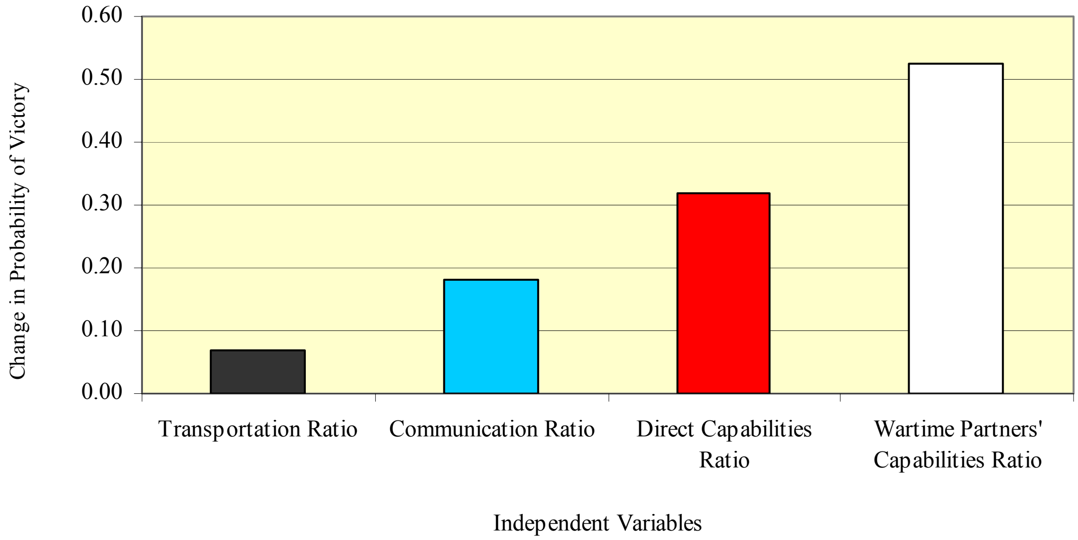

Figure 4.2: Post-World War One Substantive Effects on the Probability of War Victory: Changing from Parity to a 3:1 Advantage in Key Explanatory Variables

Chapter 5

The Empirics of Conflict Initiation

After testing the hypotheses regarding war victory and defeat, it is now time to empirically examine the relationship between transportation and communication infrastructure and the initiation of international conflict. The results of the previous chapter strongly suggest that this exploration should be an interesting and important analysis because of the previous finding that war initiating states had dramatic advantages of both transportation can communication infrastructure over their adversaries.

In order to perform this analysis, several elements are necessary to perform empirical tests of the relationship between transportation and communication infrastructure and militarized interstate dispute initiation. I first specify the research design and present the statistical findings. These areas are then followed by a discussion of the results. The discussion of a unit of analysis and the population of cases is the first area of importance, and begins below.

Unit of Analysis and Population of Cases

For this series of empirical tests on conflict initiation, I have chosen to utilize the directed-dyad unit of analysis. For every annual state pairing in the international system, there are two observations: $State_A \rightarrow State_B$ and $State_B \rightarrow State_A$. There is one such observation for every year for all states with complete data in the international system. My temporal domain is 1840 until 1993 due to the limits of my infrastructure data.

With this unit of analysis and temporal domain, there are 1,047,045 potential observations for conducting this research. However, missing data reduces the available number of cases for statistical analysis almost in half. There were 364,287 observations where the infrastructure data was missing for $State_A$, $State_B$, or both states of the directed dyad, forcing these observations to be dropped from this analysis. One control variable in particular was missing far more data than expected—regime type data. The Polity IV regime type measures (democracy minus autocracy) were missing a sizeable proportion of observations (210,475 to be exact).[1] In addition, this research also utilizes a five-year moving average to calculate changing infrastructure relations, resulting in the loss of many observations at the "beginning" of each directed dyadic data series. Seven thousand fifty-four observations were lost when calculating these five year moving averages. After accounting for these missing data issues, there is still complete data for 594,599 cases, thereby covering 56.8% of the population available.[2]

This particular unit of analysis was chosen because previous research utilized this unit of analysis to examine conflict initiation (Leeds 2003). In addition, this unit of analysis also most closely approximates the war – coalition dyad unit of analysis utilized in the previous chapter for studying war outcomes. For a "simple" bilateral war, these methods would produce identical observations, making it appropriate to discuss research

---

[1] There is some overlap between missing infrastructure data and missing polity data.

[2] Future research should increase this number dramatically as more transportation and communication infrastructure data are gathered in order to improve the state-level coverage above eighty-five percent.

findings across both studies. If the units of analysis were vastly different, it would be much more fallacious to compare the findings across the different studies.

While this study will utilize the directed-dyad unit of analysis, there were several alternative units of analysis. In particular, some previous research utilized the monadic (Enterline 1998; Tir and Diehl 1998) and the non-directed dyadic (Diehl and Kingston 1987; Huth, Bennett, and Gelpi 1992; Geller 1993) units of analysis to study conflict initiation. The following two sections briefly discuss the reasoning why these two alternatives were inappropriate and not chosen for this study.

Monadic Unit of Analysis

The monadic unit of analysis is inappropriate for examining conflict initiation because it omits the characteristics of a potential target. When deciding to initiate a militarized interstate dispute, the characteristics of the opposition should factor into the thinking of the state leaders. A state contemplating military aggression will probably be unlikely to initiate a militarized interstate dispute against a vastly more powerful adversary, while a state that is weak or weakening may make a far more suitable target for attack. For instance, examining the United States' decision to invade either Grenada or Panama in the 1980s using the monadic level of analysis would omit all the characteristics of these small Caribbean and Central American states. In particular, analyzing monads would not account for the relatively small militaries of these states when compared to the military might of the United States, or their close geographic proximity to the mainland United States. Therefore, this unit of analysis would not accurately reflect the conflict process and therefore be inappropriate. The monadic unit of analysis fails to include this sort of information, and therefore is not suitable for studying conflict initiation.

Non-Directed Dyadic Unit of Analysis

I chose not to utilize this unit of analysis because it cannot differentiate which state within a non-directed dyad initiated the dispute. The non-directed dyadic unit of analysis is an improvement over the monadic unit of analysis because it accounts for the characteristics of both potential conflicting states. However, it cannot differentiate which state in the non-directed dyad started the conflict. While this unit of analysis can detect and model the presence or absence of a dispute between the two states of the dyad, it cannot differentiate the strategic behavior of state actors and determine which of the two states actually started the dispute (Bennett and Stam 2000a, 655). Since my hypotheses are couched in terms of initiation, this unit of analysis is not refined enough to accurately test these assertions and is therefore inappropriate.

Dependent Variable

The dependent variable for this analysis is whether or not $State_A$ initiated a militarized interstate dispute against $State_B$ in year *t*. This variable takes on a value of one if there was an initiation of hostilities by $State_A$ in year *t* and zero otherwise. This data comes from the MID 3.0 data set produced by the Correlates of War Project (Ghosn, Palmer, and Bremer 2004).

Independent Variables

In order to test these assertions regarding militarized interstate dispute onset, twelve variables are necessary in order to empirically examine all these relationships. Each variable for the twelve hypotheses set forth in the theory chapter are presented below.

Transportation Infrastructure

Hypothesis Seven examines the effect of transportation infrastructure on militarized interstate dispute initiation. This measure is quantified by generating a ratio of transportation infrastructure capabilities between the warring state and its opponent or opponents using Equation 5.1 below:

Equation 5.1: Transportation Infrastructure Ratio Calculation

$$\text{Transportation Infrastructure Ratio}_{A,B} = \frac{\text{Trans. Infra.}_A}{\text{Trans. Infra.}_A + \text{Trans. Infra.}_B}$$

This ratio allows this measure to vary from zero to one. Values of one correspond with a total predominance of transportation infrastructure by State_A over State_B. Values of 0.5 correspond with infrastructure parity or equality, with both State_A and State_B possessing similar levels of infrastructure. Values of zero for this ratio correspond with State_A being at a total disadvantage in transportation infrastructure relative to State_B.

When both states have a transportation infrastructure value of zero, this variable again takes on a value of 0.5, thereby assuming that both states are equivalent when neither has a measurable transportation infrastructure system.

Utilizing ratios in this way again helps replicate my findings from the previous analysis of war outcomes. If war initiators in that analysis had greater levels of transportation infrastructure than their targets, then using the same measurement technique maintains internal consistency between models, making the results presented here more consistent and comparable with the war outcome findings. My expectation for this analysis of dispute initiation is that the transportation infrastructure ratio coefficient will be positive and statistically significant. The greater the advantage in transportation infrastructure of $State_A$ over its adversary, the greater the likelihood that $State_A$ will initiate a dispute in a particular year.

Communication Infrastructure

The measure utilized to empirically test Hypothesis Eight is quantified in a similar manner as the transportation infrastructure measure described above. I utilize the raw communication infrastructure data presented in the data chapter to quantify this term according to Equation 5.2 below:

Equation 5.2: Communication Infrastructure Ratio Calculation

$$\text{Communication Infrastructure Ratio}_{A,B} = \frac{\text{Comm. Infra.}_A}{\text{Comm. Infra.}_A + \text{Comm. Infra.}_B}$$

All the aforementioned choices and reasoning set forth when discussing transportation infrastructure also apply to communication infrastructure. I expect that this coefficient will be positive and statistically significant, indicating that the greater the relative advantage in communication infrastructure of $State_A$ over $State_B$, the greater the probability of $State_A$ initiating a militarized interstate dispute against $State_B$ in a given year.

Transportation Infrastructure and Common Border Interactive Effect

The potential interactive effect between transportation infrastructure and sharing a common border is quantified by utilizing a multiplicative interaction term. The variable for this term is created by multiplying the transportation infrastructure ratio described above by the common border variable described below. My expectation for this variable is that it should be positive and statistically significant; indicating that infrastructure is a more important consideration for initiating militarized interstate disputes when the states share a common border rather than when they are farther apart.[3]

Communication Infrastructure and Common Border Interactive Effect

Hypothesis Ten argues that there is a positive interactive effect between communication infrastructure and sharing a common border. State communication

[3] I have also tested for interactive effects between infrastructure and geography by interacting transportation and communication infrastructure ratios with continuous geographic distance measures. However, due to excessively high correlations between these interactive terms and their baseline measurements (well over 0.95), these continuous specifications were unsuitable for statistical estimation.

infrastructure should play a larger role in shaping militarized interstate dispute initiation when two states share a border. This interactive effect between communication infrastructure and geographic distance is quantified by utilizing a multiplicative interaction term by multiplying the communication infrastructure ratio described above by the common border variable described below.

Pre-World War One Transportation Infrastructure

Hypothesis Eleven deals with the relative effectiveness and importance of transportation infrastructure before World War One versus after World War One. To quantify this hypothesis, I start by creating a dichotomous variable that takes on a value of one if the year of the observation is less than 1919 and zero otherwise. I then create my interaction term by multiplying that dichotomous variable for the pre-World War One era by the transportation infrastructure ratio variable created earlier in this section. This process creates a second transportation infrastructure ratio variable that equals the transportation infrastructure ratio variable (the one created to test Hypothesis Seven above) if the year of the observation is less than or equal to 1918 (the last year of World War One) and zero if the year of the observation is greater than 1918.[4]

---

[4] It is important to mention that there is a slight change in the temporal domain for these variables from those presented in the war outcomes chapter earlier in this project. In the war outcomes analysis, the cut-off year for pre-World War One infrastructure was 1925, when there was an eight year gap between war observations. For this chapter's analysis of militarized interstate dispute onset, the cut-off date is 1918, the last year of World War One. These changes in cut-off dates (1925 versus 1918) make no statistical differences in the results presented here.

My expectation for this coefficient is that it will be positive, indicating that advantages in transportation systems over adversaries produced more bellicose policies, and thereby increase the probability of initiating a militarized interstate dispute based on calculations of transportation infrastructure prior to and including World War One than after this particular war.

Pre-World War One Communication Infrastructure

Hypothesis Twelve addresses the question of how communication infrastructure influences militarized interstate dispute initiation prior to World War One. The variable to measure this hypothesis is quantified by first creating a dichotomous variable which takes on a value of one if the year of the observation is less than 1919 and zero otherwise. I then generate this interactive term by multiplying this dichotomous variable by the communication infrastructure ratio variable created to test Hypothesis Eight. This creates a variable that equals the base communication infrastructure ratio variable (again, the one created to test Hypothesis Eight above) if the year of the observation is less than 1918 and zero if the year is less than or equal to 1918.

This coding scheme is slightly different than the one utilized in the war outcomes analysis in Chapter Four. In the war outcome analysis, the variable for this temporal variation measured post-World War One communication infrastructure. When attempting to generate a similar measure for this analysis, a problem emerged. A variable measuring post-World War One communication infrastructure had a correlation of 0.96 with the baseline communication infrastructure variable presented in this chapter. This is due in large part to different distributions of observations within the data set. While the war outcomes data was split fairly evenly between pre-World War One and post-World War One, the initiation data set used in this analysis is not evenly distributed. Eighty-eight percent of the data for this analysis come after the 1918 cut-off point, while only twelve percent of the observations come before World War One. This uneven distribution created high levels of multicolinearity, making statistical estimation impossible, necessitating a change in coding schemes for this analysis.

I expect that this variable will be positive, indicating that the overall effect of communication infrastructure has become a greater determinant of militarized interstate dispute onset since World War One. In addition, I also hold that this interactive term will be both statistically different from zero as well as statistically different from the baseline communication infrastructure ratio described above.

Western States' Transportation Infrastructure

Hypothesis Thirteen argues that considerations of transportation infrastructure are an idea of many European state leaders and military thinkers, and may not be generalizable to all the states of the international system. In order to test this relationship, I generate a variable for European state transportation infrastructure. To quantify this measure, I start by generating a variable that equals one when $State_A$ is either: 1) a European state (as categorized by the Correlates of War Project) or 2) the United States and takes on a value of zero otherwise. I then multiply this dichotomous variable with the transportation infrastructure variable previously discussed.

This variable equals the transportation infrastructure ratio variable described above for Western states and zero otherwise. When deciding whether or not to initiate a militarized interstate dispute, if considerations of transportation infrastructure are limited to only Western states, then this variable will be positive and statistically significant while the base transportation infrastructure ratio term described above will be insignificant.

Western States' Communication Infrastructure

Hypothesis Fourteen argues that communication infrastructure influences and shapes the ideas and thinking of European and American state and military leaders, and may not be generalizable to all the states of the international system. In order to test this relationship, I generate another variable for European state communication infrastructure. I start by creating a dichotomous variable that equals one if $State_A$ is 1) a European state (as categorized by the Correlates of War Project) or 2) the United States and zero otherwise. I then multiply this dichotomous variable by the communication infrastructure ratio variable described above. This variable equals the communication infrastructure ratio variable described above if the state in question is "Western" and zero otherwise. If considerations of communication infrastructure are limited to only Western states, then this variable will be positive and statistically significant while the base communication infrastructure ratio term described above will be insignificant after estimating the model.

Changing Transportation Infrastructure

The previous measures and discussions regarding infrastructure were static in nature, examining the relationship in only one year. Hypothesis Fifteen discusses and explores the dynamic relationship between transportation infrastructure and militarized interstate dispute onset. In order to test his hypothesis, it was necessary to generate a variable measuring the degree of change in relative transportation infrastructure between $State_A$ and $State_B$. I generate this variable by calculating the average change in infrastructure ratios between $State_A$ and $State_B$ over a five year period.[5] Positive values of this measure indicate that the balance of infrastructure is moving in favor of $State_A$ while negative values indicate that relative transportation infrastructure is shifting in $State_B$'s direction. My expectation for this variable is that it will be positive and statistically significant; increasing advantages in relative transportation infrastructure for $State_A$ should indicate preparations for conflict, thereby increasing the probability of initiating a militarized interstate dispute in a particular year.

Changing Communication Infrastructure

In order to test Hypothesis Sixteen, it was necessary to generate a variable measuring the changes in relative communication infrastructure between $State_A$ and $State_B$. This variable is calculated by computing the average change in communication infrastructure ratio between $State_A$ and $State_B$ over a five year period. Again, positive

[5] The statistical results are the same whether using two, three, or four year moving averages.

values of this measure indicate that the balance of relative communication infrastructure is moving more in favor of $State_A$ while negative values of this measure indicate that this balance is moving more in favor of $State_B$. My expectation is that as the relative communication infrastructure ratio shifts in favor of $State_A$, this will increase the probability of $State_A$ choosing to initiate a militarized interstate dispute against $State_B$ in a given year.

Transportation Infrastructure and National Capabilities

In order to test Hypothesis Seventeen, it was necessary to again generate an interactive term between national capabilities and transportation infrastructure. This variable is generated by multiplying the base transportation infrastructure ratio described above by the control variable for national capabilities generated below. My expectation for this variable is that it should be positive and statistically significant, indicating that when a state has a predominance of national capabilities and a predominance of transportation infrastructure, the probability of initiating a militarized interstate dispute should increase.

Communication Infrastructure and National Capabilities

This variable for measuring the final research hypothesis of this analysis is calculated by multiplying the base communication infrastructure ratio described above by the control variable for national capabilities generated below. My expectation for this variable is that it will also be positive and statistically significant, thereby indicating that when a state has both a predominance of national capabilities and a predominance of communication infrastructure, the probability of initiating a militarized interstate dispute should increase.

Control Variables

With the independent variables in place, it is now important to establish statistical controls for the analysis, and each of these control variables are discussed below. All the variables utilized for statistical controls came from EUGene version 3.040 (Bennett and Stam 2004b).

Common Border

One of the more robust findings in international relations research is that the most conflict-prone states in the international system are often neighbors (Bremer 1992; Vasquez 1995). Several authors have set forth arguments and provided evidence that sharing a common border can lead to international tension and eventual international conflict regarding the presence and location of those borders (Goertz and Diehl 1988; Starr and Most 1976). The general argument and findings are that the probability of $State_A$ initiating a dispute against $State_B$ is greater when they share a common border than when they do not share a common border. Therefore, I control for the presence or absence of a common border between states. This data comes from the Correlates of War

Direct Contiguity Data Set (Stinnett et. al. 2002) and takes on a value of one if the states share a common border and zero otherwise.

National Capability Ratio

Another often argued relationship shaping international conflict onset is the influence of state power and capabilities (see Geller 2000 for a review). There are several theories regarding the role that power plays in international relations, ranging from the balance of power theory (powerful states attack weaker states because their targets do not have the capabilities to resist) to the power parity theory (conflict is more likely when power is relatively equal because both sides believe they have some probability of victory) and the power transition theory (conflict and war is more likely when the power relationships shifts rapidly between the hegemon and a challenger state).

In order to control for these relationships involving national capabilities, I utilize the Correlates of War Project's Composite Indicator of National Capabilities (CINC) data set (Singer 1987; Singer, Bremer, and Stuckey 1972). This variable is measured by dividing the CINC score for $State_A$ by the sum total of $State_A$ and $State_B$'s CINC score. As in the previous chapter on war outcomes, this technique yields a variable that ranges from zero to one. A value of zero indicates that $State_A$ possesses no national capabilities against $State_B$ (its potential opponent) while values of one indicate that $State_A$ possesses all the national capabilities against $State_B$ and values of 0.5 represent parity between the potentially disputing states.

My expectation for the coefficient for this variable is that it will be positive and statistically significant. If state leaders are exploiting their infrastructure advantages, then they should also be exploiting other forms of physical advantage, such as advantages in national capabilities. When their state possesses an advantage in national capabilities, then they should have a higher probability of utilizing those advantages and initiating a militarized interstate dispute in a particular year. Several authors have found evidence to support this idea that advantages in national capabilities do make states more likely to initiate militarized interstate disputes, therefore it should follow that I come up with similar statistical results (Bennett and Stam 2004; Leeds 2003; Morgan and Palmer 2000).

Pre-World War One Era

In order to statistically examine these changing effects of both transportation and communication infrastructure over time, it is necessary to include a variable in order to separate and distinguish between observations occurring before and after World War One. Therefore, I include a dichotomous variable that takes on a value of one if the year of the observation is less than 1919 and zero otherwise. I have no a priori expectations about the direction of this variable.

Western States

Several hypotheses concerning the behavior of Western states argue that these states will act and behave differently than other states regarding relative infrastructure. Again, because there are measurements that are capturing the differences between groups within the data, it is necessary to include a dichotomous variable to differentiate between the two different populations. This variable takes on a value of one when $State_A$ in the directed dyad is either the United States or a European state and zero otherwise. My expectation for this variable is that it will be positive; because the majority of major powers are in Europe, as well as all the European states being in such close proximity to each other, there should be a heightened probability of militarized interstate dispute initiation in any particular year.

Joint Democracy

The "Democratic Peace" argument is one of the more robust statistical findings regarding interstate peace in international relations today (Oneal, Oneal, Maoz and Russett 1996; Maoz and Abdolali 1989). Given the findings in the war outcome analysis of the previous chapter, it is certainly possible that there is a degree of correlation between democracy and infrastructure. Therefore, due to its prevalence in the literature, I control for domestic regimes in this analysis. I start by computing a democracy score for each state in the directed dyad by taking the Polity IV "DEMOC" variable and subtracting the Polity IV "AUTOC" variable obtained through EUGene (Bennett and Stam 2000). This technique produces a scale ranging from ten (the most democratic states in the international system) to negative ten (the most autocratic and totalitarian governments). With these measures in hand, I then generate a dichotomous variable that takes on a value of one if both states in the directed dyad have democracy scores greater than six and zero otherwise.

My expectation for this variable's coefficient is that it should be negative, indicating that democratic states should have a reduced probability of initiating a militarized interstate dispute against other democratic states.[6] With the previous chapter's finding that democracy is not a significant indicator of war outcomes once statistical models control for infrastructure, including regime variables become much more important in order to test whether or not this is a generalizable phenomenon. If democracy would become an insignificant variable for interstate peace once controlling for infrastructure, this would call into question a large research paradigm in international relations research and policy.

Bilateral Military Alliance

The presence or absence of military alliances can also contribute to the onset of militarized interstate disputes. It is possible that infrastructure could have some correlation effect with alliances. An important consideration for any alliance is that the alliance be credible between the signatory parties. Infrastructure could provide some

---

[6] Continuous measures of regime similarity work equally well in the models of conflict initiation presented here, and yield the same general statistical results as those presented later in this chapter.

form of physical credibility for an alliance, thereby necessitating the inclusion of a control variable for the presence or absence of a bilateral alliance.

Data for this measure comes from the Correlates of War Formal Alliance Data Set version 3.03 (Gibler and Sarkees 2004). This variable takes on a value of one if $State_A$ has any type of formal military alliance (a mutual defense pact, an entente, or a neutrality agreement) with $State_B$ and zero otherwise. My expectation is that this variable will be negative, indicating that states will not initiate militarize interstate disputes against their allies.

Peace Years

The final set of control variables for this analysis are intended to capture the effects of spatial and time dependence of potential disputing states. One statistical concern that arises when estimating models of conflict onset or initiation is temporal dependence (Beck, Katz, and Tucker 1998, 1261). States that are at peace with each other tend to remain peaceful, while states that more recently had conflict between them tend to have more conflicts between them in the present timeframe. Likewise, the decision to initiate a militarized interstate dispute in a particular year does not happen in a vacuum; the decision to initiate may be spurred on by other state leaders choosing conflict over peace in a particular year. By not controlling for these two forms of dependence (thereby violating the independence of observations assumption in statistics), statistical estimates can be biased, potentially casting doubt on any research findings (Beck, Katz, and Tucker 1998, 1261).

In order to control for potential temporal dependence inherent in the conflict process, it was necessary to utilize Beck, Katz, and Tucker's BTSCS (Binary Time-Series Cross-Section) Stata 8 "ado" program file (Beck, Katz, and Tucker 1998). This statistical program file generates four control variables in order to rectify the potential problems often associated with temporal dependence. The first variable created is called "Peace Years" from this point forward. This variable is a count variable for the number of years since the last militarized interstate dispute onset between the two states.[7] The other three variables generated by this statistical package create three cubic spline functions, which also help control for temporal dependence. These three spline variables are called "Cubic Spline 1" through "Cubic Spline 3" throughout the rest of the tables in this chapter.

Statistical Estimation Techniques

In order to estimate these statistical models, I utilize logistic regression. This analysis technique corresponds with the dichotomous nature of the dependent variable, which is the presence or the absence of a militarized interstate dispute initiation in a particular year (Long 1997). In addition, I also utilize robust standard errors in order to help correct for the lack of independence between observations. Finally, by including the peace years and cubic spline functions in this analysis, the potential bias of temporal dependence is also controlled for using the techniques presented here.

---

[7] Using the onset of militarized interstate disputes as the temporal factor is the commonly-accepted approach in quantitative international relations. This analysis has also been replicated using the initiation of militarized interstate disputes as the variable for establishing temporal dependence, however there are no changes in the statistical findings when using either of these approaches for generating these control measures.

Statistical Results

In the previous empirical chapter on war outcomes, analyses were broken down to examine the model with only the transportation infrastructure variables, then only the communication infrastructure variables, followed by a fully-specified model. I performed these separate analyses because certain variables (the communication infrastructure variable in particular) moved in and out of statistical significance based on the specification of the model. By contrast, this analysis will only estimate one statistical model. Altering the specification of this model does not alter or change any of the empirical findings presented here.

Table 5.1 presents the logistic regression results for the conflict initiation analysis. The Baseline Model presented in the far right column of Table 5.1 presents a statistical model of militarized interstate dispute initiation using only the control variables for comparison purposes.

[*Insert Table 5.1 about here*.]

Model One in Table 5.1 estimates the model using all the variables set forth in the previous sections. Looking first at the transportation infrastructure coefficients, some interesting relationships emerge from these statistical findings. First, the coefficient for the baseline transportation infrastructure ratio is negative, not positive as originally hypothesized. This runs counter to my hypothesis. While this variable is insignificant, it is only marginally insignificant. The decision to employ one-tailed or two-tailed tests of statistical significance is the difference in whether or not this coefficient is taken as being relevant t. The coefficient for Pre-World War One transportation infrastructure is positive and statistically significant in accordance with my theory, indicating that greater advantages in transportation infrastructure led to more conflict-prone policies before World War One. The coefficients for Western Transportation infrastructure ratio, changing infrastructure ratio, and the interaction term between transportation infrastructure ratio and national capabilities are all statistically insignificant, therefore further discussion of their signs is unnecessary.

The communication infrastructure variables also produce some rather interesting findings. The baseline communication infrastructure ratio coefficient is negative and statistically significant, thereby indicating that advantages in communication infrastructure actually *decrease* the probability of initiating a militarized interstate dispute in a particular year. This variable appears to operate in a similar manner to the baseline transportation infrastructure ratio measure describe above, and is contradictory to my hypothesized relationship as well as the findings regarding war outcomes in Chapter Four. The coefficient for pre-World War One Communication infrastructure ratio is positive and statistically significant, indicating that advantages in communication infrastructure prior to World War One made states more likely to initiate militarized interstate disputes, however given the relative magnitude of this coefficient in comparison to the dichotomous Pre-World War One era control variable, further discussion of this finding will have to wait until the predicted probabilities can be calculated in order to better illustrate the relationship between communication infrastructure and militarized interstate dispute initiation. The coefficient for changing communications infrastructure is also positive as hypothesized and statistically significant. This indicates that changes of relative communication infrastructure in favor of a potential initiator promote more bellicose policies. Finally, the interactive effect of communication infrastructure with sharing a common border (Hypothesis Twelve), the interactive term between transportation infrastructure ratio and national capabilities (Hypothesis Seventeen), and the interactive term between communication infrastructure ratio and national capability ratio (Hypothesis Eighteen) are all insignificant, thereby requiring no further discussion.

Regarding the control variables, there are no surprises in these results. They all possess the anticipated signs and are statistically significant. The common border coefficient and the national capabilities coefficient are both positive and statistically significant. This indicates that states are more likely to initiate disputes against other states that share a common border with them rather than those separated by some amount of geographic space and that when states possess an advantage in material capabilities, they will be more likely to exploit that advantage and initiate a militarized interstate dispute against a less-prepared state. The coefficients for joint democracy and peace years are negative and statistically significant, indicating that democratic states are less likely to initiate militarized interstate disputes against other democratic states and that the longer the time of peace between states, the less likely that there is an initiation of hostilities between the states. The coefficient for bilateral military alliances is negative as hypothesized, however this variable barely fails to reach conventional levels of statistical significance. Overall, the inclusion of infrastructure variables makes statistically significant improvements to the model's fit over the baseline model (Chi^2 (12) = 115.15, $p < 0.000$).

Discussion

With the model estimated and presented, there is an important question that needs to be addressed. That question is by what mechanism does the measure for both transportation and communication infrastructure go from being negative in this model of militarized interstate dispute initiation to positive in the model for war outcomes. There are two general ideas which can potentially explain this change in signs between stages of the conflict process.

One possible explanation for the change in signs for transportation and communication infrastructure variables is through strategic behavior involved in the many stages of the conflict process. From the time a militarized interstate dispute is initiated against another state, there are several stages where decisions are made by state leaders and officials that can shape, alter, or change the probability that a simple dispute becomes an interstate war (Bremer and Cusack 1995). There are decisions whether or not to utilize military force, rather than just threatening military force. There are decisions whether or not to respond to or reciprocate the challenge from an adversary. There is the decision to escalate from the simple use of force to a full-scale war engagement versus an adversary. At any one of these stages in the chain of conflict, decisions can be made which alter the relationship between infrastructure and international conflict. Only after future research examines the role of infrastructure at more of these different stages of conflict can we better understand how and why there is a negative relationship between transportation and communication infrastructure in cases of conflict initiation while there is a positive relationship between both transportation and communication infrastructure and victory in war.

A second (but generally weak) possible explanation for the change in signs for transportation and communication infrastructure ratio in the militarized interstate dispute initiation model presented here is an omitted variable bias. Previous research has argued that the omission of a particular variable can alter and change the statistical inferences produced through an underspecified statistical model (Gail, Weiand, and Piantadosi 1984; Marias and Wecker 1998). It is possible (however rather unlikely) that there is a missing factor that is not controlled for in this model that would turn the coefficients for both transportation and communication infrastructure from a negative sign to a positive sign.

This omitted variable explanation possesses two important problems, however. First, in order to include a control variable in a statistical model, there needs to be some theoretical justification for its inclusion (Ray 2003). Without a theoretical justification, it can be inappropriate to include a particular control variable. Second, *all* models of militarized interstate dispute onset or initiation are often assumed to omit explanatory variables. The model presented here only explains approximately twenty-five percent of the variance in the dependent variable, and this model is fairly typical of those published throughout the literature on interstate conflict.[8] As a general observation, models of conflict onset or initiation often have greater areas of unexplained variance than they do explained variance. Therefore, this omitted variable critique does not possess much veracity.

---

[8] The pseudo R^2 of the fully-specified model was 0.256.

A potential reason for the counterintuitive finding regarding the changing transportation infrastructure ratio coefficient (which was only marginally insignificant) may have to do with economic reasons that are not included within the statistical models presented here. As mentioned earlier in this project, the costs involved in constructing infrastructure can often be rather high. In order to have the resources necessary to build infrastructure (and therefore have larger values for this variable), a state may be going through positive economic growth that is bringing wealth and prosperity to the state. When a state is becoming wealthier, they may be building and developing infrastructure because they have the economic resources to do so. In order to help maintain economic prosperity during periods of economic success, they may become less likely to initiate military disputes with other states because conflicts and wars are costly. The transportation infrastructure measure presented here may be capturing this sort of positive business cycle relationship; when this indicator is greater, there may be greater levels of economic prosperity, resulting in lower levels of conflict initiation. Only the inclusion of macroeconomic indicators, such as changes to real GDP or stock market values, could test this assertion. These types of data are unavailable; therefore future research may have to explore this possibility in greater detail.

Substantive Effects

With this discussion of the results completed, it is now important to examine the relative effect of infrastructure on predicting militarized interstate dispute initiation. In order to examine the substantive effects of these models, it was necessary to set a baseline for the all the variables in these models. The variables for sharing a common border, Western states, Pre-World War One Era, joint democracy, and military alliances were all set at their modal categories of zero. The peace years and the three spline variables were all set at their mathematical means. The transportation infrastructure ratio, the communication infrastructure ratio, and the national capability ratio variables were all set equal to 0.5, indicating a condition of relative parity between the two potentially disputing states. I also set the changing transportation and communication infrastructure variables were equal to zero, thereby assuming that the two states had maintained their relative infrastructure over the previous five years. Finally, I then computed all the interaction terms for the remaining variables in the model in order to generate a baseline probability of militarized interstate dispute initiation.

With this baseline in hand, I performed my first analysis of substantive effects by individually varying the transportation infrastructure ratio, communication infrastructure ratio, and the national capabilities ratio from their assumed baseline value of 0.5 to a value of 0.75, which corresponds with a 3:1 advantage in each of these three indicators.[9] I perform this variation analysis for both the Pre-World War One and the Post-World War One eras (thereby necessitating a change in the Pre-World War One dichotomous variable for three of these probabilities as well). The resulting changes in predicted probabilities are depicted in Figure 5.1 below.

[*Insert Figure 5.1 about here*.]

---

[9] This variation in these three ratios corresponds with a shift of less than one standard deviation in all of these measures. Specific descriptive statistics can be found in Table A.3 of the Appendix in this dissertation.

The resulting changes in the predicted probability of dispute initiation paints a very interesting picture. These findings indicate that the role of transportation infrastructure has changed dramatically since the conclusion of World War One. Before World War One, transportation infrastructure was a dramatic influence on whether or not a state would initiate a militarized interstate dispute. During this era, moving from transportation infrastructure parity to a 3:1 advantage in transportation infrastructure yields an increase in the probability of initiation by 0.00027, while a similar change in national capabilities ratios during that era only yields a change in the probability of initiation of 0.0008. Therefore, before World War One, transportation infrastructure had three times the probabilistic influence of national capabilities. In addition, this finding is in accordance with my hypothesized relationship. After World War One, however, transportation infrastructure is a much smaller indicator of conflict initiation. Moving from transportation infrastructure parity to a 3:1 advantage yields a change in the probability of -0.00006, an effect slightly smaller than the effect of national capabilities during the contemporary era. While still playing somewhat of a role, this finding must be tempered somewhat by the coefficient sign that is contrary to my hypothesized relationship.

The differences in influence of communication infrastructure before and after World War One appears as hypothesized when examining the changes in predicted probabilities and not the simple coefficients presented earlier. Before World War One, communication infrastructure plays a miniscule role in the probability of initiating a militarized interstate dispute against a potential adversary. Shifting from parity to a 3:1 advantage only yields a change in the predicted probability of initiation of -0.00001.

After World War One, however, communication infrastructure appears to play a fairly substantial role in shaping the decision to initiate a dispute. During this time period, a shift from communication infrastructure parity to a 3:1 infrastructure advantage produces a reduction in the probability of conflict of -0.00013, again an amount greater than the same shift from parity to a 3:1 advantage in national capabilities. These findings again must be somewhat tempered by these coefficients possessing the opposite sign of the originally hypothesized relationship.

Another important substantive effect to analyze is the effect of changing relative infrastructure between two potentially disputing states. For this analysis, I varied the changing transportation infrastructure, changing communication infrastructure and the national capabilities ratio by one-half standard deviation and generated the change in predicted probabilities.[10] The results are depicted in Figure 5.2 below.

[*Insert Figure 5.2 about here*.]

The changes in predicted probabilities show that shifts in relative infrastructure do play a role in shaping conflict initiation. A one-half standard deviation in changing communication infrastructure ratio results in an increase in the probability of dispute initiation of 0.0006. A similar one-half standard deviation increase in national capabilities yields a change of 0.0007, a rather similar amount. Therefore, it would appear that an increasing balance of relative communication infrastructure in favor of a potential aggressor appears to lead to higher probabilities of dispute initiation.

---

[10] A one-half standard deviation change in national capabilities ratio equates to a change from parity to a 2.5: 1 relative advantage.

Correlation Concerns

In models with large numbers of interactive terms, multicolinearity can be a problem. Table 5.2 below provides a correlation matrix for the analyses presented in this chapter.

[*Insert Table 5.2 about here.*]

High correlation coefficients can be a cause for concern, and there are several correlations which warrant some attention. The correlation coefficient between pre-World War One transportation infrastructure and pre-World War One communication infrastructure is 0.877. Likewise, the correlation coefficient between the transportation and communication infrastructure interacted with common borders is high as well (0.877). The measures for Western transportation and communication infrastructure ratios are also highly correlated (0.933), as well as the correlation between the common border control variable and the interactive term between common borders and both transportation and communication ratios (0.866 and 0.895, respectively). This many high degrees of correlation are cause for anxiety, as they inflate standard errors and can create insignificant statistical results and could potentially explain this analyses weak statistical findings.

However, in this analysis it appears that these high correlations are not cause for concern or the cause for the weak empirical findings. In order to determine if this correlation issue was a problem, I estimated the model with each and every variable by itself. In all these models, using any one of these six aforementioned, utilizing the highly correlated variables by themselves does not change ether their sign or their statistical significance level, thereby indicating that this correlation concern does not appear to alter or hamper the statistical findings presented here.

Conclusions

This chapter presented a statistical examination of transportation and communication infrastructure and how these systems influence the initiation of militarized interstate disputes. Three of my research hypotheses were directly supported through the statistical evidence provided by this analysis. The effect of transportation infrastructure before World War One (Hypothesis Nine) was a dramatic influence on the probability of initiating a dispute against another state during that era, even surpassing the effect of national capabilities during that time frame. Likewise, there was support for the hypothesis regarding differences in communication infrastructure eras (Hypothesis Ten). Before World War One, communication infrastructure had little probabilistic influence on the initiation of disputes, while communication infrastructure has a larger influence in the probability of conflict initiation than do national capabilities after that war. However, this finding must be somewhat tempered because the effect of communication infrastructure is negative, and not positive as originally hypothesized. Finally, changes in relative communication infrastructure (Hypothesis Sixteen) also appear to promote conflict initiation. As the advantage in communication infrastructure shifts in favor of a potential initiator, they do appear to exploit their growing advantage and initiate disputes with other states.

A null finding within this chapter provides evidence that the research here is generalizable to all the states of the international system. Hypothesis Thirteen and Hypothesis Fourteen argued the possibility that infrastructure may only be a consideration of leaders within Western states, such as the United States and Europe. However, there was no empirical support for these assertions. Therefore, it would appear that the findings presented here appear to apply to all the states of the international system.

There was one counterintuitive finding: that the interaction term between sharing a common border and transportation infrastructure is negative instead of positive as hypothesized. In addition, a number of the hypotheses tested in this chapter failed to reach levels of conventional significance: the interactive effect between communication infrastructure and sharing a common border (Hypothesis Twelve), the effect of changing relative transportation infrastructure ratios (Hypothesis Fifteen), and the interactive effect between either transportation or communication infrastructure and national capabilities (Hypothesis Seventeen and Eighteen, respectively) were all insignificant.

Chapter Five Tables

Table 5.1: Logistic Regression Model Results for Militarized Interstate Dispute Initiation

Dependent Variable: Initiation of a MID by State$_A$ against State$_B$ in year *t*

***N* = 594,599**	**Model One**		**Baseline Model**	
Transportation Variables				
Transportation Infrastructure Ratio $_{A,B}$	-0.27900 (0.18434)			
Pre-World War One Transportation Infrastructure Ratio $_{A,B}$	1.18586 (0.25034)	**		
Transportation Infrastructure Ratio x Common Border	-0.39024 (0.20999)	*		
"Western" Transportation Infrastructure Ratio $_{A,B}$	0.07384 (0.23387)			
Changing Transportation Infrastructure Ratio $_{A,B}$	-0.82950 (0.56107)			
Transportation Infrastructure Ratio x National Capability Ratio	0.03180 (0.23771)			
Communication Variables				
Communication Infrastructure Ratio $_{A,B}$	-0.47806 (0.18746)	**		
Pre-World War One Communication Infrastructure Ratio $_{A,B}$	0.52109 (0.26727)	*		
Communication Infrastructure Ratio x Common Border	0.02468 (0.23741)			
"Western" Communication Infrastructure Ratio $_{A,B}$	0.19149 (0.25112)			
Changing Communication Infrastructure Ratio $_{A,B}$	1.16964 (0.25721)	**		
Communication Infrastructure Ratio x National Capability Ratio	-0.18019 (0.25019)			
Control Variables				
Common Border	2.30619 (0.13676)	**	2.07717 (0.07560)	**
National Capability Ratio	0.37630 (0.12358)	**	0.28819 (0.06203)	**
Pre-World War One Era	-0.81320 (0.16372)	**	0.15869 (0.06671)	**
Western State$_A$	0.15521 (0.15723)		0.24284 (0.05497)	**
Jointly Democratic	-0.20041 (0.09946)	**	-0.17783 (0.09810)	**
Bilateral Military Alliance	-0.04497 (0.08048)		-0.04866 (0.07951)	
Peace Years	-0.53755 (0.01698)	**	-0.54935 (0.01692)	**
Cubic Spline 1	-0.00286 (0.00015)	**	-0.00293 (0.00015)	**
Cubic Spline 2	0.00146 (0.00010)	**	0.00149 (0.00010)	**
Cubic Spline 3	-0.00006 (0.00002)	**	-0.00006 (0.00002)	**
Constant	-2.85151 (0.11520)	**	-3.10180 (0.09282)	**
Log-Likelihood Ratio	-8619		-8669	
Pseudo R2	0.2563		0.2513	

Notes: ** Sig. $p < 0.05$ * Sig. $p < 0.10$ Robust standard errors are listed in parentheses.
All significance tests are two-tailed.

Table 5.2: Correlation Matrix for Militarized Interstate Dispute Initiation

N = 594, 599	Transportation Infrastructure Ratio $_{A,B}$	Pre-World War One Transportation Infrastructure Ratio $_{A,B}$	Transportation Infrastructure Ratio x Common Border	"Western" Transportation Infrastructure Ratio $_{A,B}$	Changing Transportation Infrastructure Ratio $_{A,B}$	Transportation Infrastructure Ratio x National Capability Ratio	Communication Infrastructure Ratio $_{A,B}$	Pre-World War One Communication Infrastructure Ratio $_{A,B}$	Communication Infrastructure Ratio x Common Border	"Western" Communication Infrastructure Ratio $_{A,B}$	Changing Communication Infrastructure Ratio $_{A,B}$	Communication Infrastructure Ratio x National Capability Ratio	Common Border	Pre-World War One Era	Western State$_A$	National Capability Ratio	Jointly Democratic	Bilateral Military Alliance	Peace Years	Cubic Spline 1	Cubic Spline 2
Pre-World War One Transportation Infrastructure Ratio $_{A,B}$	0.278																				
Transportation Infrastructure Ratio x Common Border	0.078	0.107																			
"Western" Transportation Infrastructure Ratio $_{A,B}$	0.568	0.322	0.032																		
Changing Transportation Infrastructure Ratio $_{A,B}$	0.000	-0.057	-0.021	-0.031																	
Transportation Infrastructure Ratio x National Capability Ratio	0.702	0.231	0.042	0.517	-0.024																
Communication Infrastructure Ratio $_{A,B}$	0.676	0.192	0.034	0.461	0.000	0.500															
Pre-World War One Communication Infrastructure Ratio $_{A,B}$	0.179	0.877	0.084	0.279	-0.060	0.164	0.258														
Communication Infrastructure Ratio x Common Border	0.032	0.082	0.877	0.021	-0.022	0.012	0.067	0.110													
"Western" Communication Infrastructure Ratio $_{A,B}$	0.493	0.298	0.028	0.934	-0.015	0.455	0.524	0.320	0.036												
Changing Communication Infrastructure Ratio $_{A,B}$	0.000	0.014	-0.001	0.078	0.077	0.010	0.000	0.014	-0.001	0.089											
Communication Infrastructure Ratio x National Capability Ratio	0.541	0.183	0.020	0.451	-0.003	0.863	0.655	0.196	0.028	0.473	0.022										
Common Border	0.000	0.067	0.866	-0.002	-0.024	-0.013	0.000	0.070	0.895	0.006	-0.001	-0.013									
Pre-World War One Era	0.327	0.114	0.023	0.280	0.000	0.773	0.263	0.084	0.013	0.256	0.000	0.782	0.001								
Western State$_A$	0.001	0.760	0.076	0.144	-0.075	0.030	0.001	0.796	0.078	0.162	0.018	0.022	0.087	0.000							
National Capability Ratio	0.414	0.273	0.050	0.900	-0.012	0.387	0.379	0.275	0.052	0.913	0.091	0.361	0.047	0.236	0.198						
Jointly Democratic	0.000	-0.079	-0.003	0.089	0.021	-0.024	0.000	-0.083	-0.003	0.089	0.030	-0.012	-0.003	0.000	-0.104	0.141					
Bilateral Military Alliance	0.000	-0.056	0.214	-0.040	-0.019	-0.032	0.000	-0.059	0.222	-0.038	0.007	-0.019	0.248	0.000	-0.074	-0.008	0.096				
Peace Years	-0.003	-0.064	-0.036	0.097	-0.031	-0.023	-0.002	-0.066	-0.039	0.083	0.021	-0.030	-0.042	-0.007	-0.078	0.111	0.147	0.151			
Cubic Spline 1	0.003	0.075	0.024	-0.089	0.025	0.023	0.001	0.078	0.025	-0.076	-0.022	0.027	0.027	0.006	0.096	-0.103	-0.148	-0.159	-0.963		
Cubic Spline 2	0.003	0.076	0.023	-0.087	0.024	0.023	0.001	0.080	0.024	-0.075	-0.021	0.027	0.026	0.006	0.098	-0.102	-0.148	-0.159	-0.954	1.000	
Cubic Spline 3	0.003	0.079	0.022	-0.084	0.022	0.022	0.001	0.082	0.023	-0.072	-0.022	0.026	0.025	0.006	0.101	-0.098	-0.147	-0.159	-0.938	0.997	0.999

Chapter Five Figures

Figure 5.1

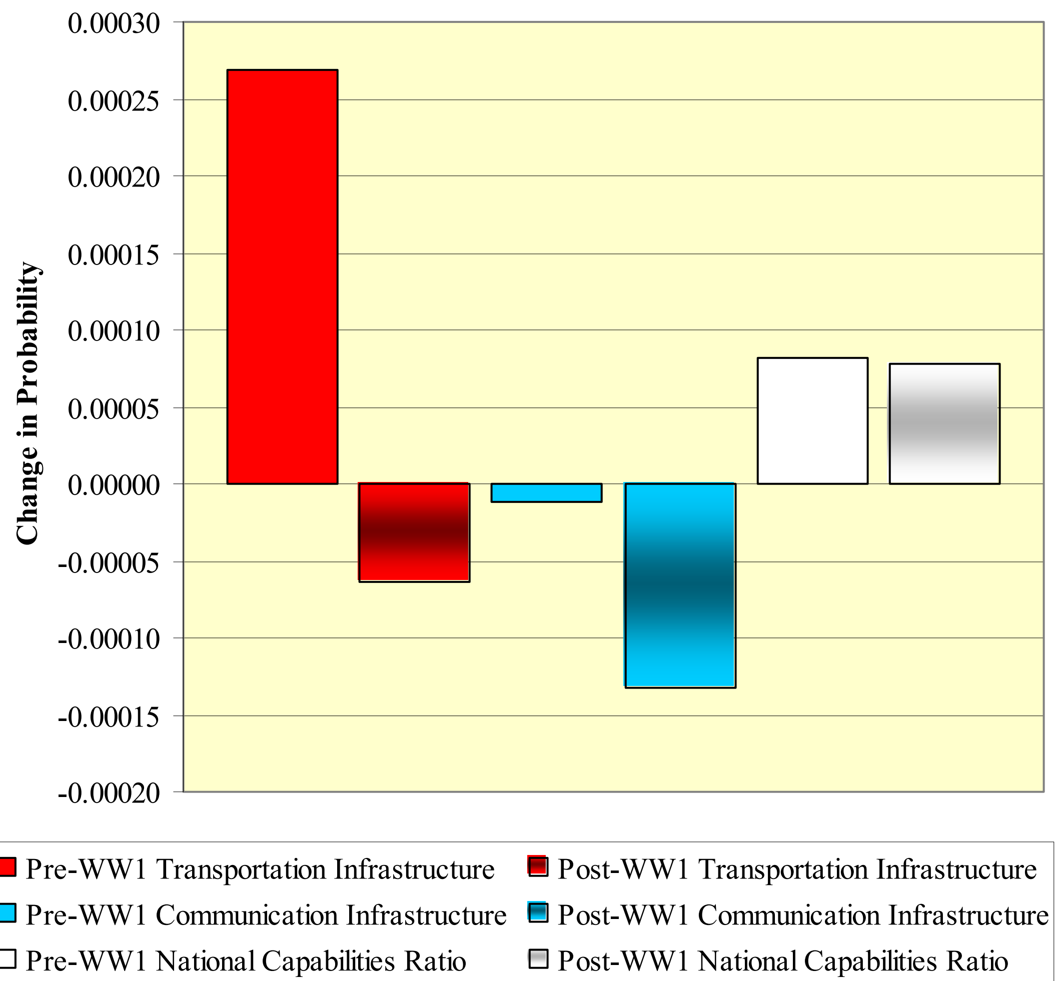

Figure 5.1: Absolute Change in Predicted Probability of MID Initiation, Moving From Parity to a 3:1 Relative Advantage in Key Variables, 1845 - 1993

Figure 5.2

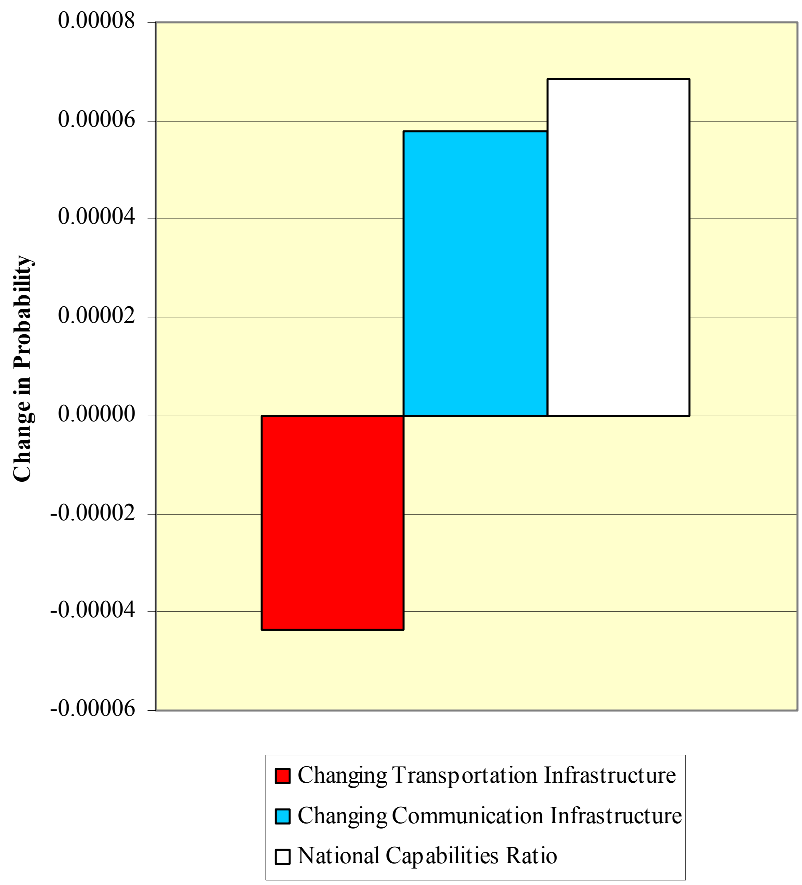

Figure 5.2: Absolute Change in Predicted Probability of MID Initiation, One-Half Standard Deviation Change in Relative Infrastructure, 1845 – 1993.

Chapter 6

Conclusions and Extensions

Chapter One of this dissertation established the need for research concerning infrastructure. Chapter Two outlined and elucidated a theoretical basis for why infrastructure would play a role in international relations, and more specifically how political leaders examine relative infrastructure and make decisions of war and peace based on these observations. Chapter Three presented the data for transportation and communication infrastructure, providing the first data set for infrastructure that comprises both a long time span (1840 – 1993) and a large number of states. Chapter Four analyzed the relationship between transportation and communication infrastructure and victory in wartime. Chapter Five empirically examined the relationship between infrastructure and the initiation of militarized interstate disputes. With these various analyses completed, it is now important to draw some conclusions and extensions about this project.

This chapter will consist of several sections. The first section will reiterate the empirical findings of this dissertation for both war outcomes and militarized interstate dispute initiation. The second section will discuss some potential extensions to the infrastructure data presented and utilized throughout the course of this dissertation. The third section of this chapter will briefly discuss several areas of future research that could follow from this project.

Results Summary

Overall, there were three empirical studies performed in this analysis. The first analysis examined infrastructure data in the process of outlining and introducing the data in Chapter Three. The second empirical study examined the effect of transportation and communication infrastructure on war outcomes in Chapter Four. The third empirical analysis studied the effect of transportation and communication infrastructure on the initiation of militarized interstate disputes in Chapter Five. The subsections that follow will again briefly summarize the results of these analyses.

Infrastructure Data

The first empirical analyses of this dissertation surrounded the reliability and prima fascia ability of transportation and communication infrastructure data to accurately reflect this characteristic in the states of the international system. The historical case studies tracking Germany's infrastructure from 1840 until 1993 appeared to correspond with and follow changes occurring within that state over that time frame. When used to make predictions about certain events where other measures utilized in international relations had failed, the infrastructure data were able to make accurate predictions of the outcomes of four wars: The Franco-Prussian War, the Sinai War, the Six-Day War, and the Yom Kippur War. Overall, there was fairly convincing evidence that the infrastructure data were reflecting the transportation and communication characteristics and systems of the states in the international system.

War Outcomes

The second empirical analysis of this dissertation examined the relationship between advantages and disadvantages in infrastructure and winning interstate wars. The results of this analysis were fairly robust; transportation infrastructure was a fairly important factor in states winning and losing wars before World War One. After World War One, transportation infrastructure still plays a role in shaping war outcomes, but this role is relatively small when considered against other explanations of war outcomes. Since World War One, communication infrastructure appears to play an important role in which states win and lose wars.

An important finding stemming from this analysis is that democracy, development, and initiation are insignificant predictors of war outcomes after controlling for the effects of infrastructure. However, this analysis also provided evidence that democracies are more likely than their authoritarian counterparts to construct and build infrastructure. The presence of better infrastructure in democratic states provides them with advantages on the battlefield, resulting in higher probabilities of winning the wars they become involved in.

The results of this analysis also make two suggestions to American policy-makers regarding their program of "Strategic Mobility" originally mentioned in Chapter One. The first possible recommendation that this research could suggest is that when considering whether to spend money on either transportation or communication infrastructure, the answer would appear that money spent on communication infrastructure would be better spent than on transportation infrastructure.[1] Since communication infrastructure has approximately twice the impact on the probability of victory of transportation infrastructure, money spent on communications infrastructure rather than on transportation infrastructure would appear to be better spent.

The second possible recommendation for policy-makers is that spending on transportation and communication infrastructure, while being somewhat effective in producing improved probabilities of war victory, could be the third consideration on a potential list of spending priorities. The largest indicator of war victory was the capabilities possessed by a state's wartime partners. The second largest indicator of war victory according to the models presented in Chapter Four was direct national capabilities. Communication infrastructure possesses less than half the substantive effect of both of these measures in terms of in promoting victory in wartime. This finding suggests that the priority of spending funds in order to win wars should be on maintaining wartime partners (such as working within International organizations such as the United Nations and NATO) and on maintaining numerical advantages (meaning spending more on military recruitment), two areas of current United States policy that are facing difficult times over the War in Iraq.

---

[1] I could not find specific breakdowns of spending for transportation and communication infrastructure within this program.

Militarized Interstate Dispute Initiation

The findings for the initiation of militarized interstate disputes, while interesting, are not quite as dramatic as those revealed when studying the outcomes of interstate wars. Overall, there was only strong evidence supporting three hypotheses. First, before World War One, when a state possessed an advantage in transportation infrastructure over a potential adversary, they were more likely to utilize that advantage and initiate a militarized interstate dispute against an adversary. Second, when the balance of relative communication infrastructure is shifting in favor of a potential aggressor, then that state is more likely to initiate a militarized interstate dispute against a potential adversary. Third, communication infrastructure prior to World War One played little role in shaping international conflict behavior.

One of the null empirical results, however, should be interpreted as an important finding. One of the theories and concerns presented here was the idea that considerations of transportation and communication infrastructure could have been important only to Western states, such as the United States and Europe. The results in this chapter indicate that there is no statistical difference between the states where many of these considerations of infrastructure were explicitly discussed and the states that did not expressly concern themselves with infrastructural considerations throughout the world.

There were two unexpected empirical findings within this chapter. The transportation infrastructure coefficient in this model indicates that as the advantage in transportation infrastructure increases for a particular state, that state appears to become *less* likely to initiate a militarized interstate dispute against a potential adversary. An identical relationship appears to exist between communication infrastructure and conflict initiation; greater advantages in relative communication infrastructure possess a pacifying effect rather than a conflict-evoking response.

While both these relationships operated in the opposite direction of my hypotheses, delving deeper into these relationships between infrastructure and conflict initiation should be a priority. While the coefficient for communication infrastructure did possess the opposite sign of my theory, the substantive effect of this communication infrastructure measure was larger than the substantive effect of national capabilities, which is included in almost all models of conflict initiation in the broad literature of international relations. Simply put, communication infrastructure is explaining more about the probability of conflict initiation than are national capabilities. A better understanding why these potentially important statistical findings are negative instead of positive should be a priority in continuing research.

Infrastructure Data Extensions

One question that always arises with data collections is what improvements can be made to the data set? How can the data collected here be improved? There are two broad enhancements that can and should be made in the near future in order to improve upon this data set: 1) updating the data set to the present and 2) expanding the realm and measures of communication infrastructure are two important areas of extension for this research project.

Updating the infrastructure measures up to the current year is the first general improvement that can be made to the data set assembled here. While this project covers a large number of states in the international system (again, approximately eighty-five percent), it is still not the full population of states. Other enduring research programs, such as the Correlates of War Project, have managed to collect data on every state in the international system from 1816 until the present day. Updating this data set up through the present day, as well as finding information on currently missing data within these data sets, should be a research priority.

Expanding the communications infrastructure data set is a second data set extension that should be performed. The current cut-off date of 1993 omits the communications explosion of the 1990s from this analysis. Over that decade, two simultaneous expansions of communications infrastructure occurred that are not accounted for in this analysis, but will be important when updating this data set to the present year.

The rapid growth of cellular telephone networks is the first rapid change in communications infrastructure during the 1990s that may need to be included in updates to the communication infrastructure data set presented in this dissertation. It is possible that these cellular telephone networks may fall under the “classical” category of telephones in service; however it is necessary to confirm this and ensure that this is the case. If cellular telephones are not included in measures of telephone lines in service, then it would be necessary to introduce a third measurement into the factor analysis approaches presented in Chapter Three.

The explosive growth of the Internet during the 1990s is the second rapid change in communications infrastructure that must eventually be incorporated into future research. Commentary on a number of levels and venues identify that the rapid growth of Internet communications are shaping the world, and excluding this consideration in future iterations of this data set would reduce the validity of the work presented here. It is possible that the number of telephones in service could be capturing some of the internet capabilities of states. Because "dial-up" services require phone lines to function, the number of telephones in service could capture some of the computing infrastructure of states. However, as technology progresses, the rapid rise in availability of both cable and digital subscriber line (DSL) internet connections may reduce this potential link between telephones and internet infrastructure. One potential measure for the internet infrastructure of a state may be the number of internet service providers available in a particular state; however it should be a priority of future research to find and incorporate some measure of internet connectivity into this broader category of communications infrastructure presented here.

Research Extensions

A question that often arises from research is a question of applicability. Are the findings presented in the project confined to only the immediate research question, or can the findings and examination be applied to other research questions. In this section, I will argue that infrastructure has the potential to be examined and applied to a very wide variety of international relations studies and efforts. This section will briefly outline a number of potential avenues for future research in areas of international conflict, international political economy, and democratization.

International Conflict

In the realm of international conflict, the idea that infrastructure can influence state behavior has several avenues of future research. The formation of military alliances and the choice of military strategy that a state utilizes to fight a particular war are two areas where infrastructure potentially can play a significant role in shaping state behavior.

The formation of military alliances is one potential area of future examination regarding the role of infrastructure. One of the concerns for any state in considering whether to form an alliance with another state is the credibility of that alliance commitment. If a potential ally is credible, then there is a better possibility of forming an alliance with that particular state. Likewise, if that potential ally is not credible in their alliance commitment, then there will be a reduced probability of forming an alliance (Maoz 2000).

It is possible to argue that infrastructure provides a physical form of credibility for potential allies. A state with good infrastructure can move their military forces quickly, having a greater capacity to come to a potential ally's aid in time of crisis or conflict. Therefore, since the state can react quickly in times of distress, there should be an increased probability of forming a military alliance. Therefore, states with good infrastructure (thereby possessing a physical credibility) should be more likely to be involved in a military alliance with other state, holding everything else constant.

Military strategy is a second area where introducing considerations of infrastructure could make a contribution to better understanding state behavior. Research on how military strategy influences other behaviors is widely recognized. Military strategy has been tied to whether or not a state wins a war (Rieter and Stam 1998), how long a particular war lasts (Bennett and Stam 1996), and the onset of international conflict (Reiter 1999).

However, there is little known about why a particular state chooses a specific military strategy. Reiter and Meek (1999) presented one of the only empirical analyses as to why a state would choose maneuver strategies over all other alternatives. Their findings were that democratic states and states with greater steel consumption were more likely to utilize maneuver strategies. A case can be made that better infrastructure within the state can lead to utilizing maneuver strategies more often. States where transportation and communication systems are prevalent can assume that these technologies have filtered into their respective militaries. With better transportation systems, the states under examination may be better suited to maintain the operational pace necessary for maneuver operations. On the flip side, when states have poor or non-existent infrastructure, attrition or punishment strategies may be more suited for war fighting because of their reduced necessity for speed of supply and mobility. Future research should empirically examine these relationships.

International Political Economy

International Political Economy is a second area where infrastructure could play a significant role in developing a greater understanding of international relations. More specifically, the idea that infrastructure can play a role in international economics has come up in particular in two areas of previous research—interstate trade and foreign direct investment.

Interstate trade is one area where infrastructure could potentially play a significant role in shaping behavior. Actors within states examine the macroeconomic conditions of the states they are trading with. For instance, firms operating within states will examine the regime type of the governments with which they are considering trading between, because democratic governments are more supportive of patent claims, guaranteeing intellectual property rights, and have a lower risk of asset seizure than do their authoritarian counterparts (Hegre 2000; Keshk, Polins, and Reuveny 2004).

Infrastructure is another macroeconomic condition that firms operating within state will take into consideration when deciding whether or not to trade between states. When states possess better, more improved infrastructure, transportation costs and communication and coordination difficulties will be reduced, driving their production costs down, increasing profits, and therefore promoting and increasing levels of interstate trade. When the state being considered as a potential venue for interstate trade has poor or non-existent infrastructure, the transportation and coordination difficulties will be greater, driving costs up, decreasing profits, and resulting in lower levels of interstate trade.[2]

Foreign Direct Investment (FDI) is a second area in international political economy where infrastructure could play an important part in shaping behaviors. Building infrastructure is often a consideration when considering whether to invest in a particular state (Levy 1996). Oftentimes, foreign direct investments will earmark funds for certain projects in order to improve the infrastructure surrounding them in order to increase profitability and facilitate economic interactions surrounding a particular investment project. These earmarked funds will be sunk costs that cannot be recovered if the project does not perform as anticipated. Therefore, foreign direct investment should be more prevalent in states where the infrastructure is better because there will be lower sunk costs involved in building or developing a project within that state.

Post-Colonial Regime Survival

Democratic regime survival is a third potential area of future research utilizing infrastructure as an important explanatory variable. Previous research in this field has argued that certain colonial powers, in particular, the British, built, developed, and left behind better infrastructure systems than other former colonial powers, such as Spain, France, and Belgium (Englebert 2000; Bernard, Reenok and Nordstrom 2004). However, these previous analyses do not separately test for the effects of infrastructure on the

---

[2] Preliminary research into this question presented at the Midwest Political Science Association meetings in 2005 provided initial empirical support for these assertions.

survival of these post-colonial regimes. They all operate under the assumption that simple, dichotomous variables for "Britain," France," and "Spain" capture these infrastructural differences in former colonizers.

With the data provided through this project, it is now possible to see whether or not there is a separate, measurable effect of infrastructure on post-colonial regime survival. Because infrastructure has the potential to increase state capacity, there should be a positive relationship between infrastructure and democratic regime survival. With the data generated here from this project, empirical testing of these assertions is possible.[3]

Final Conclusions

This project has examined the role of infrastructure in shaping international conflict. It has advanced a more generalizable definition of infrastructure, as well as helping to categorize the many forms of infrastructure. This research also produced the first cross-national data set on infrastructure that captured the amounts of these systems for the vast majority of states in the international system from 1840 until 1993.

---

[3] This research is currently underway with Michael Bernard. Our preliminary findings support these assertions presented here.

Bibliography

Adams, Colin and Ray Laurence, eds. 2001. *Travel and Geography in the Roman Empire*. New York, New York: Routledge.

Ahmed, Raisuddin and Cynthia Donovan. 1992. *Issues of Infrastructural Development: A Synthesis of the Literature*. Washington, D.C.: International Food Policy Research Institute.

Barbieri, Katherine. 1996. "Economic Interdependence: A Path to Peace or a Source of Interstate Conflict?" *Journal of Peace Research* 33: 29-49.

Bardou, Jean-Pierre, Jean-Jacques Chanaron, Patrick Fridenson, and James M. Laux. 1982. *The Automobile Revolution: The Impact of an Industry*. Chapel Hill, North Carolina: University of North Carolina Press.

Beck, Nathaniel, Jonathan Katz, and Richard Tucker. 1997. "Taking Time Seriously: Time-Series - Cross-Section Analysis with a Binary Dependent Variable." *American Journal of Political Science* 42 (October): 1260-1288.

Bennett, D. Scott and Alan Stam. 1996. "The Duration of Interstate Wars, 1816-1986." *The American Political Science Review* 90: 239-257.

____________. 2000a. "Research Design and Estimator Choices in the Analysis of Interstate Dyads: When Decisions Matter." *Journal of Conflict Resolution* 44: 653 – 685.

____________. 2000b. "*EUGene*: A Conceptual Manual." *International Interactions* 26: 179 – 204.

____________. 2004. *The Behavioral Origins of War*. Ann Arbor: University of Michigan Press.

Bennett, D. Scott and Timothy Nordstrom. 2000. "Foreign Policy Substitutability and Internal Economic Problems in Enduring Rivalries." *The Journal of Conflict Resolution* 44: 33 – 61.

Bernard, Michael, Christopher Reenock and Timothy Nordstrom. 2004. "The Legacy of Overseas Colonialism on Democratic Survival." *International Studies Quarterly* 48: 225 – 250.

Bishop, Matthew. 2000. *Pocket Economist*. London: Profile Books.

Black, William R. 1999. "Sustainable Transportation: A US Perspective." *Journal of Transport Geography* 4: 151 - 159.

Boulding, Kenneth. 1963. *Conflict and Defense: A General Theory*. New York: Harper and Row.

Bowen, Jeremy. 2003. *Six Days: How the 1967 War Shaped the Middle East*. New York, New York: Simon and Schuster.

Bremer, Stuart. 1992. "Dangerous Dyads: Conditions Affecting the Likelihood of Interstate War, 1816-1985." *Journal of Conflict Resolution* 36: 309-341.

Bremer, Stuart and Thomas R. Cusack. 1995. *The Process of War: Advancing the Scientific Study of War*. Luxembourg: Gordon and Breach Publishers.

____________. 2000. "Who Fights Whom, When, Where, and Why?" Chapter 2 in *What Do We Know About War?* ed. John A. Vasquez. Lanham, Maryland: Rowman & Littlefield.

Bueno de Mesquita, Bruce. 1981. *The War Trap*. New Haven: Yale University Press.

Bueno de Mesquita, Bruce, James D. Morrow, and Ethan Zorick. 1997. "Capabilities, Perception, and Escalation." *The American Political Science Review* 91 (March): 15-27.

Bueno de Mesquita, Bruce, Alastair Smith, Randolph M. Siverson, and James D. Morrow. 2003. *The Logic of Political Survival*. Cambridge, Massachusetts: MIT Press.

Cate, Curtis. 1985. *The War of the Two Emperors: The Duel Between Napoleon and Alexander: Russia, 1812*. New York: Random House.

Chalmers, Malcolm and Lutz Unterseher. 1988. "Is There a Tank Gap? Comparing NATO and Warsaw Pact Tank Fleets." *International Security* 13: 5-49.

Channon, Geoffrey. 2001. *Railways in Britain and the United States, 1830 – 1940*. Burlington, Vermont: Ashgate Press.

Chevallier, Raymond. 1976. *Roman Roads*. Berkley, California: University of California Press.

Congressional Budget Office. 1997. "Moving U.S. Forces: Options for Strategic Mobility." February 2005. http://www.cbo.gov/ftpdocs/0xx/doc11/Stratmob.pdf (February 2005).

Correlates of War Project. 2005. "State System Membership List, v2004.1" http://correlatesofwar.org (May 10, 2005).

Cropper, Maureen L. and Elizabeth Kopits. 2003. *International Road Foundation—World Road Statistics*. World Bank Research Division. March 9, 2005. http://econ.worldbank.org/view.php?topic=14&type=18&id=23079 (March 9, 2005).

Davis, Adrian L. 1999. "Promoting Sustainable Transport in England: Principles and Practice." *Journal of Transport Geography* 4: 67 – 70.

Diamond, Larry. 1992. "Promoting Democracy." *Foreign Policy* 87: 25 – 46.

Diamond, D. and N. Spence. 1989. *Infrastructure and Industrial Costs in British Industry*. London: The Department of Trade and Industry.

Diehl, Paul F. and Jean Kingston. 1987. "Messenger or Message? Military Buildups and the Initiation of Conflict." *Journal of Politics* 49: 801-813.

Doyle, Michael W. 1997. *Ways of War and Peace*. New York, NY: W.W. Norton.

Dupuy, Trevor Nevitt. 1979. *Numbers, Predictions, and War: Using History to Evaluate Combat Factors and Predict the Outcomes of Battles*. Indianapolis, Indiana: Bobbs-Merrill.

Dupuy, Trevor Nevitt. 1983. *Analysis of Factors that Have Influenced Outcomes of battles and Wars: A Database of Battles and Engagements, Final Report*. 6 vols. Dunn Loring, VA: Historical Evaluation and Research Organization.

Dupuy, R. Ernest and Trevor N. Dupuy. 1986. *The Encyclopedia of Military History from 3500 BC to the Present*. 2nd rev. ed. New York: Harper and Row.

Engels, Donald W. 1978. *Alexander the Great and the Logistics of the Macedonian Army*. Berkley, California: University of California Press.

Englebert, Pierre. 2000. "Pre-Colonial Institutions, Post-Colonial States, and Economic Development in Tropical Africa." *Political Research Quarterly* 53: 7 – 36.

Enterline, Andrew J. 1998. "Regime Changes and interstate Conflict, 1816 – 1992." *Political Research Quarterly* 51: 385 – 409.

Farber, Henry S. and Joanne Gowa. 1995. "Polities and Peace." *International Security* 20: 123 – 146.

Farrington, J.H., and A.A. Ryder. 1993. "The Environmental Assessment of Transport Infrastructure and Policy." *Journal of Transport Geography* 1: 102-118.

Fearon, James D. 1994. "Signaling versus the Balance of Power and Interests: An Empirical Analysis of a Crisis Bargaining Model." *Journal of Conflict Resolution* 38: 236 – 269.

____________. 1995. "Rationalist Explanations for War." *International Organization* 49: 379 – 414.

Gail, M.H., S. Weiand, and S. Piantadosi. 1984. "Biased Estimates of Treatment Effect in Randomized Experiments With Nonlinear Regressions and Omitted Covariates." *Biometrika* 71(3): 431 – 444.

Gartzke, Erik. 1999. "War is in the Error Term." *International Organization* 53: 567-587.

Geller, Daniel S. 1990. "Nuclear Weapons, Deterrence, and Crisis Escalation." *The Journal of Conflict Resolution* 34: 291 – 310.

____________. 1993. "Power Differentials and War in Rival Dyads." *International Studies Quarterly* 37: 173 – 193.

____________. 2000. "Material Capabilities: Power and International Conflict." Chapter 12 in *What Do We Know About War?* ed. John A. Vasquez. Lanham, Maryland: Rowman & Littlefield.

Ghosn, Faten, Glenn Palmer, and Stuart Bremer. 2004. "The MID3 Data Set, 1993–2001: Procedures, Coding Rules, and Description." *Conflict Management and Peace Science* 21: 133 – 154.

Gibler, Douglas M., and Meredith Sarkees. 2004. "Measuring Alliances: the Correlates of War Formal Interstate Alliance Data set, 1816-2000." *Journal of Peace Research* 41: 211 – 222.

Goertz, Gary and Paul Diehl. 1988. "Territorial Changes and Militarized Conflict." *Journal of Conflict Resolution* 32: 03 – 122.

Greenwald, Douglas, ed. 1994. *The McGraw Hill Encyclopedia of Economics*. New York: McGraw Hill.

Hegre, Harvard. 2000. "Development and the Liberal Peace: What Does It Take to Be a Trading State?" *Journal of Peace Research* 37: 5 – 30.

Henderson, Earl Anthony. 1998. "The Democratic Peace Through the Lens of Culture, 1820 – 1989." *International Studies Quarterly* 42: 461 – 484.

Hensel, Paul R. 1996. "Charting a Course to Conflict: Territorial Issues and Militarized Interstate Disputes, 1816-1992." *Conflict Management and Peace Science* 15: 43-73.

Herbst, Jeffrey Ira. 2000. *States and Power in Africa: Comparative Lessons in Authority and Control*. Princeton, New Jersey: Princeton University Press.

Hoyle, Brian and Richard Knowles. 1998. *Modern Transport Geography, Edition Two*. New York: John Wiley and Sons.

Huth, Paul. 1988. *Extended Deterrence and the Prevention of War*. New Haven: Yale University Press.

Huth, Paul and Bruce Russett. 1993. "General Deterrence Between Enduring Rivals: Testing Three Competing Models." *The American Political Science Review* 87: 61 – 73.

Huth, Paul, D. Scott Bennett, and Christopher Gelpi. 1992. "System Uncertainty, Risk Propensity, and International Conflict Among the Great Powers." *Journal of Conflict Resolution* 36: 478 – 517.

Jaggers, Keith, and Ted Robert Gurr. 1995. "Tracking Democracy's Third Wave with the Polity III Data." *Journal of Peace Research* 32: 469 – 482.

Janis, Irving Lester. 1972. *Victims of Groupthink: a Psychological Study of Foreign Policy Decisions and Fiascos*. Boston: Houghton Mifflin.

Jervis, Robert. 1976. *Perception and Misperception in International Politics*. Princeton: Princeton.

Justman, Moshe. 1995. "Infrastructure, Growth and the Two Dimensions of Industrial Policy." *The Review of Economic Studies* 62: 131 – 157.

Kane, Thomas M. 2001. *Military Logistics and Strategic Performance*. Portland, Oregon: Frank Cass Publishing.

Karnow, Stanley. 1983. *Vietnam: A History*. New York, New York: Penguin Books.

Keshk, Omar M.G., Brian M. Polins and Rafael Reuveny. 2004. "Trade Still Follows the Flag: The Primacy of Politics in a Simultaneous Model of Interdependence and Armed Conflict." *Journal of Politics* 66: 1155 – 1179.

Kim, Jae-On and Charles W. Mueller. 1978a. *Introduction to Factor Analysis: What it is and How to Do It*. Newbury Park, California: Sage Publications.

______. 1978b. *Factor Analysis: Statistical Methods and Practical Issues*. Newbury Park, California: Sage Publications.

King, Gary, Robert O. Keohane and Sidney Verba. 1994. *Designing Social Inquiry: Scientific Inference in Qualitative Research*. Princeton, New Jersey: Princeton University Press.

Kugler, Jacek and Douglas Lemke. 1998. *Parity and War: Evaluations and Extensions of The War Ledger*. Ann Arbor: University of Michigan Press.

Leeds, Brett Ashley. 2003. "Do Alliances Deter Aggression? The Influence of Military Alliances on the Initiation of Militarized Interstate Disputes." *American Journal of Political Science* 47: 427 – 439.

Lemke, Douglas. 2003. "African Lessons for International Relations Research." *World Politics* 56: 114 – 138.

Lemke, Douglas and William Reed. 2001. "The Relevance of Politically Relevant Dyads." *Journal of Conflict Resolution* 45: 126 – 144.

Levite, Ariel. 1989. *Offense and Defense in Israeli Military Doctrine*. Boulder, Colorado: Westview Press.

Levy, Jack S. 1988. "Domestic Politics and War." *Journal of Interdisciplinary History* 18: 653 – 673.

Levy, Sidney M. 1996. *Build, Operate, Transfer: Paving the Way for Tomorrow's Infrastructure*. New York: John Wiley and Sons, Inc.

Lichtarowicz, Anya. 2005. "Ebola, Marburg Vaccine 'Success.'" *BBC News:* http://news.bbc.co.uk/1/hi/world/africa/4612339.stm (June 5th, 2005).

Linneker, Brian, and Nigel Spence. 1996. "Road Transport Infrastructure and Regional Economic Development: The Regional Development Effects of the M25 London Orbital Motorway." *Journal of Transport Geography* 4: 77 – 92.

Long, J. Scott. 1997. *Regression Models for Categorical and Limited Dependent Variables*. Thousand Oaks, California: Sage Publications.

Machiavelli, Niccollo. 2005. *The Prince*. Boston, Massachusetts: Bedford Press.

Maoz, Zeev. 2000. "Alliances: The Street Gangs of World Politics—Their Origins, Management, and Consequences, 1816-1986." Chapter 6 in *What Do We Know About War?* ed. John A. Vasquez. Lanham, Maryland: Rowman & Littlefield.

Maoz, Zeev and Nasrin Abdolali. 1989. "Regime Types and International Conflict, 1817 – 1976." *Journal of Conflict Resolution* 33: 3 – 35.

Maoz, Zeev and Bruce Russett. 1993. "Normative and Structural Causes of the Democratic Peace, 1946-1986." *American Political Science Review* 87: 624 – 638.

Marias, M. Laurentius and William E. Wecker. 1998. "Correcting for Omitted-Variables and Measurement-Error Bias in Regression with an Application to the Effect of Lead on IQ." *Journal of the American Statistical Association* 93: 494 – 505.

Mitchell, Brian R. 1998. *International Historical Statistics: Africa, Asia, and Oceana, 1750 – 1993.* Third Edition. New York, New York: Stockton Press.

Mitchell, Brian R. 1998. *International Historical Statistics: The Americas, 1750 – 1993.* Fourth Edition. New York, New York: Stockton Press.

Mitchell, Brian R. 1998. *International Historical Statistics: Europe, 1750 – 1993.* Fourth Edition. New York, New York: Stockton Press.

Modelski, George and William Thompson. 1995. *Leading Sectors and World Powers: The Coevolution of Global Economics and Politics*." Colombia, South Carolina: University of South Carolina Press.

Morgan, Patrick. 1983. *Deterrence: A Conceptual Analysis*. 2nd ed. Beverly Hills: Sage.

Morgan, T. Cliff and Glenn Palmer. 1997. "A Two-Good Theory of Foreign Policy: An Application to Dispute Initiation and Reciprocation." *International Interactions* 22: 225 – 244.

Morgan, T. Cliff and Glenn Palmer. 2000. "A Model of Foreign Policy Substitutability: Selecting the Right Tool for the Right Job(s)." *The Journal of Conflict Resolution* 44: 11-32.

Morris, Lloyd and Kendall Smith. *Ceiling Unlimited: The Story of American Aviation from Kitty Hawk to Supersonics*. New York: Macmillan.

Morrison, Catherine J., and Amy Ellen Schwartz. 1996. "State Infrastructure and Productive Performance." *The American Economic Review* 86: 1095 – 1111.

Most, Benjamin A. and Harvey Starr. 1993. *Inquiry, Logic, and International Politics*. Colombia, South Carolina: University of South Carolina Press.

Myers, Gregory W. 1994. "Competitive Rights, Competitive Claims: Land Access in Post-War Mozambique." *Journal of Southern African Studies* 20: 603 – 632.

Newell, Clayton R. 1991. *The Framework of Operational Warfare*. New York: Routledge.

Nickles, David Paull. 2003. *Under the Wire: How the Telegraph Changed Diplomacy*. Cambridge, Massachusetts: Harvard University Press.

Oneal, John R., Frances H. Oneal, Zeev Maoz, and Bruce Russett. 1996. "Liberal Peace: Interdependence, Democracy, and International Conflict." *Journal of Peace Research* 33: 11-28.

Oneal, John R. and James Lee Ray. 1997. "New Tests of the Democratic Peace: Controlling for Economic Interdependence, 1950-1985." *Political Research Quarterly* 50: 751-775.

Oneal, John R. and Bruce M. Russett. 1999. "The Kantian Peace: The Pacific Benefits of Democracy, Interdependence, and International Organizations, 1885-1992." *World Politics* 52: 1-37.

____________. 1997. "The Classical Liberals Were Right: Democracy, Interdependence, and Conflict 1950-1985." *International Studies Quarterly* 41: 267 – 294.

Organski, A.F.K. and Jacek Kugler. 1980. *The War Ledger*. Chicago: University of Chicago Press.

Oslin, George P. 1992. *The Story of Telecommunications*. Macon, Georgia: Mercer University Press.

Pearce, David W., ed. 1992. *The MIT Dictionary of Modern Economics*. Cambridge, Mass.: MIT Press.

Phelps, Major Angela R. 1996. "Strategic Mobility." *Army Logistician*. PB 700-96-2 28(3). http://www.almc.army.mil/alog/issues/mayjun/ms042.htm (March 2005)

Pirie, Gordon. 1993. "Transport, food insecurity and food aid in sub-Saharan Africa." *Journal of Transport Geography* 1: 12 – 19.

Posen, Barry R. 1984. *The Sources of Military Doctrine: France, Britain, and Germany between the World Wars.* Colombia: University of South Carolina Press.

Ray, James Lee. 2003. "Explaining Interstate Conflict and War: What Should Be Controlled For?" *Conflict Management and Peace Science* 20: 1 – 31.

Reed, William. 2000. "A Unified Model of Conflict Onset and Initiation." *American Political Science Review* 44: 84 – 93.

Rees, E.A. 1995. *Stalinism and Soviet Rail Transport, 1928 – 1941*. New York, New York: St. Martin's Press.

Reiter, Dan. 1999. "Military Strategy and the Outbreak of International Conflict: Quantitative Empirical Tests, 1903 – 1992." *Journal of Conflict Resolution* 43: 366 – 387.

Reiter, Dan, and Curtis Meek. 1999. "Determinants of Military Strategy, 1903-1994: A Quantitative Empirical Test." *International Studies Quarterly* 43: 363 – 387.

Reiter, Dan, and Alan C. Stam III. 1998. "Democracy, War initiation, and Victory." *The American Political Science Review* 92: 377-389.

Reitveld, Piet and Frank Bruinsma. 1998. *Is Transport Infrastructure Effective? Transport Infrastructure and Accessibility: Impacts on the Space Economy*. Heidelberg, Germany: Springer.

Roberts, Bryan R. 1989. "Urbanization, Migration, and Development." *Sociological Forum* 4: 665 – 691.

Rowland, Wade. 1997. *Spirit of the Web: The Age of Information from Telegraph to Internet*. Toronto: Somerville House.

Rousseau, Jean Jacques. 1762 [2002]. *The Social Contract and the First and Second Discourses*. Trans. Susan Dunn. New Haven, CT: Yale University Press.

Russett, Bruce. 1993. *Grasping the Democratic Peace*. Princeton, New Jersey: Princeton University Press.

Russett, Bruce and John R. Oneal. 2001. *Triangulating Peace: Democracy, Interdependence, and International Conflict*. New York, New York: Norton.

Russett, Bruce, John R. Oneal, and David R. Davis. 1998. "The Third Leg of the Kantian Tripod for Peace: International Organizations and Militarized Disputes, 1950-1985." *International Organization* 52: 441 – 467.

Sagan, Scott D. 1997. “Why do States Build Nuclear Weapons? Three Models in Search of a Bomb.” *International Security* 21: 54-86.

Sarkees, Meredith Reid (2000). "The Correlates of War Data on War: An Update to 1997." *Conflict Management and Peace Science*, 18: 123 – 144.

Shah, Anwar. 1992. “Dynamics of Public Infrastructure, Industrial Productivity, and Profitability.” *The Review of Economics and Statistics* 74: 28-36.

Signorino, Curtis S. and Jeffery M. Ritter. 1999. “Tau-b or Not Tau-b: Measuring the Similarity of Foreign Policy Positions.” *International Studies Quarterly* 43: 115-144.

Singer, J. David, Stuart Bremer, and John Stuckey. 1972. “Capability Distribution, Uncertainty, and Major Power War, 1820-1965.” In *Peace, War and Numbers*, ed. Bruce M. Russett. Beverly Hills: Sage, 19-48.

Singer, J. David. 1987. "Reconstructing the Correlates of War Dataset on Material Capabilities of States, 1816-1985." *International Interactions*, 14: 115 – 132.

Spiro, David E. 1994. “The Insignificance of the Liberal Peace.” *International Security* 19: 50 – 86.

Stam, Allan C. III. 1996. *Win, Lose, or Draw: Domestic Politics and the Crucible of War*. Ann Arbor: University of Michigan Press.

Starr, Harvey and Benjamin Most. 1976. “The Substance and Study of Borders in International Relations Research.” *International Studies Quarterly* 20: 581 – 620.

Stinnett, Douglas M., Jaroslav Tir, Philip Schafer, Paul F. Diehl, and Charles Gochman. 2002. "The Correlates of War Project Direct Contiguity Data, Version 3." *Conflict Management and Peace Science* 19: 58 – 66.

Stoll, Richard J. and Michael D. Ward, eds. 1989. *Power in World Politics*. Boulder: Lynne Reinner.

Sun Tzu. 500 B.C.E. [1971]. *The Art of War*. Trans. Samuel B. Griffith. New York: Oxford University Press.

Thucydides. 1993. *On Justice, Power, and Human Nature*. Translated by Paul Woodruff. New York: W.W. Norton and Company.

“Tight budgets heighten congressional scrutiny of F/A-22 fighters.” *The Associated Press*: http://www.accessnorthga.com/news/ap_newfullstory.asp?ID=35284

Tir, Jaroslav, Philip Schafer, Paul Diehl, and Gary Goertz. 1998. "Territorial Changes, 1816-1996: Procedures and Data" *Conflict Management and Peace Science* 16: 89 – 97.

Tir, Jaroslav, and Paul Diehl. 1998. "Demographic Pressure and Interstate Conflict: Linking Population Growth and Density to Militarized Disputes and Wars, 1930 – 1989." *Journal of Peace Research* 35: 319 – 339.

The Economist. 2001. "Upsetting China: Arms Sales to Taiwan." March 15, 2001.

The Economist. 2005. "When the Partying Has to Stop: Dealing with North Korea." February 10, 2005.

Tuchmann, Barbara W. 1994. *The Guns of August*. New York: Ballantine Publishing.

Tucker, Spencer C., ed. 1996. *The European Powers in the First World War: An Encyclopedia*. New York: Garland Publishers.

USNI Military Database. 2004. "Main Battle Tank (USA) – M1 Abrams." http://www.periscope1.com/demo/weapons/gcv/tanks/w0003593.html.

Vasquez, John. 1993. *The War Puzzle*. Cambridge: Cambridge University Press.

____________. 1995. "Why Do Neighbors Fight? Proximity, Interaction, or Territoriality." *Journal of Peace Research* 32: 277 – 293.

Van Creveld, Martin. 1991. *Technology and War: From 2000 B.C. to the Present.* New York: Free Press.

____________. 2004. *Supplying War: Logistics from Wallenstein to Patton*. Second Edition. New York, New York: Cambridge University Press USA.

Van Evera, Steven. 1984. "The Cult of the Offensive and the Origins of the First World War." *International Security* 9: 58 – 107.

Waltz, Kenneth N. 1979. *Theory of International Politics*. New York: McGraw-Hill.

Wang, Kevin, and James Lee Ray. 1994. "Beginners and Winners: The Fate of Initiators of Interstate Wars Involving Great Powers Since 1495." *International Studies Quarterly* 38: 139 – 154.

Webley, Simon. 1985. *Stiffening the Sinews of the Nations: Economic Infrastructure in the United States, United Kingdom, and Canada*. London: British-North American Committee.

Winston, Brian. 1998. *Media Technology and Society: A History: From the Telegraph to the Internet*. New York: Routledge.

Appendix

Descriptive Statistics for Statistical Analyses

Table A.1: Descriptive Statistics for Transportation and Communication Infrastructure, 1840 – 1993

N = 9,214	**Mean**	**Std. Dev.**	**Minimum**	**Maximum**
Transportation Infrastructure	0.240	1	0	31.704
Communication Infrastructure	0.725	1	0	15.742

Table A.2: Descriptive Statistics for War Outcomes Analysis Performed in Chapter Four

N **= 205**	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**
War Victory	0.5463	0.4991	0.0000	1.0000
Transportation Infrastructure Ratio $_{A,B}$	0.4758	0.3529	0.0000	1.0000
Post-World War One Transportation Infrastructure Ratio $_{A,B}$	0.2286	0.3272	0.0000	0.9984
Geographic Distance x Transportation Infrastructure Ratio $_{A,B}$	887	2190	0.0000	15949
Communication Infrastructure Ratio $_{A,B}$	0.4789	0.3351	0.0000	1.0000
Post-World War One Communication Infrastructure Ratio $_{A,B}$	0.2283	0.3376	0.0000	1.0000
Geographic Distance x Communication Infrastructure Ratio $_{A,B}$	956	2226	0.0000	15684
Development Ratio $_{A,B}$	0.4864	0.3176	0.0000	1.0000
Regime $_{A}$ x Initiation $_{A}$ (Polynomial Term 1)	1.1546	0.5102	0.6901	3.1623
Regime $_{A}$ x Initiation $_{A}$ (Polynomial Term 2)	-0.5126	1.5338	-7.2814	0.5120
Regime $_{A}$ x Target $_{A}$	-1.5220	4.9947	-10.0000	10.0000
Initiation $_{A\ against\ B}$	0.4098	0.4930	0.0000	1.0000
Direct Capabilities Ratio $_{A,B}$	0.3334	0.3102	0.0014	0.9895
Wartime Partners' Capabilities Ratio $_{A,B}$	0.1974	0.2623	0.0000	0.8096
Military Quality $_{A}$	3.6970	9.4250	0.0050	79.8333
Maneuver Strategy $_{A}$, Attrition Strategy $_{B}$	0.4485	0.1963	0.0000	0.7500
Attrition Strategy $_{A}$, Maneuver Strategy $_{B}$	0.0780	0.2689	0.0000	1.0000
Attrition Strategy $_{A}$, Attrition Strategy $_{B}$	0.0780	0.2689	0.0000	1.0000
Punishment Strategy $_{A}$, Attrition Strategy $_{B}$	0.6732	0.4702	0.0000	1.0000
Attrition Strategy $_{A}$, Punishment Strategy $_{B}$	0.0439	0.2054	0.0000	1.0000
Terrain	0.1268	0.3336	0.0000	1.0000
Strategy-Terrain Interaction	2.3076	1.0459	0.5000	5.0000

Table A.3: Descriptive Statistics for Militarized Interstate Dispute Initiation Analysis Performed in Chapter Five

N = 594,599	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**
Initiation	0.003	0.053	0.000	1.000
Transportation Infrastructure Ratio $_{A,B}$	0.500	0.362	0.000	1.000
Pre-World War One Transportation Infrastructure Ratio $_{A,B}$	0.077	0.238	0.000	1.000
Transportation Infrastructure Ratio x Common Border	0.020	0.113	0.000	1.000
"Western" Transportation Infrastructure Ratio $_{A,B}$	0.221	0.372	0.000	1.000
Changing Transportation Infrastructure Ratio $_{A,B}$	0.023	0.107	-0.093	2.007
Transportation Infrastructure Ratio x National Capability Ratio	0.302	0.360	0.000	1.000
Communication Infrastructure Ratio $_{A,B}$	0.500	0.323	0.000	1.000
Pre-World War One Communication Infrastructure Ratio $_{A,B}$	0.077	0.227	0.000	1.000
Communication Infrastructure Ratio x Common Border	0.020	0.109	0.000	1.000
"Western" Communication Infrastructure Ratio $_{A,B}$	0.209	0.345	0.000	1.000
Changing Communication Infrastructure Ratio $_{A,B}$	0.020	0.096	-2.270	1.083
Communication Infrastructure Ratio x National Capability Ratio	0.287	0.334	0.000	1.000
Common Border	0.040	0.195	0.000	1.000
National Capability Ratio	0.500	0.439	0.000	1.000
Pre-World War One Era	0.154	0.361	0.000	1.000
Western State$_A$	0.304	0.460	0.000	1.000
Jointly Democratic	0.111	0.315	0.000	1.000
Bilateral Military Alliance	0.075	0.263	0.000	1.000
Peace Years	34	30	0	153
Cubic Spline 1	-34092	60959	-345680	0
Cubic Spline 2	-60498	116388	-668168	0
Cubic Spline 3	-84825	179809	-1060928	0

CURRICULUM VITA

Christopher Eric Housenick

Education:

Ph.D. in Political Science, The Pennsylvania State University, June 2005.
M.A. in Political Science, The Pennsylvania State University, April 2001.
B.A. in Political Science, Slippery Rock University of Pennsylvania, May 1999.

Awards:

Robert Friedman Award for Graduate Teaching; Department of Political Science, The Pennsylvania State University (2004)
Best Masters Essay Award; Department of Political Science, The Pennsylvania State University (2001)
Outstanding Academic Achievement in Political Science. Department of Political Science, Slippery Rock University of Pennsylvania (1999)

Publication:

Housenick, Christopher E. 2005. 'Cuba." In *Defense and Security: A Compendium of National Armed Forces and Security Policies*, ed. Karl DeRouen, Jr. and Uk Heo. Santa Barbara, California: ABC-Clio Publishers.

Teaching Experience:

Seminar on Terrorism (PLSC 439), Spring 2005
Introduction to International Relations (PLSC 014), Summer 2004
Controversies in International Relations (PLSC 497F), Fall 2003 and Spring 2004
Introduction to American National Government (PLSC 001), Summer 2003

Personal Information:

Born September 14th, 1972 in Cumberland, Maryland
Served in the U.S. Army, December 1991 – April 1996 (82nd Airborne Division, April 1992 – February 1996).