

ESSAYS ON APPLIED MICROECONOMICS

by

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B.S., Northwest Missouri State University, 2003

AN ABSTRACT OF A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Economics
College of Arts and Sciences

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2008

Abstract

This first essay empirically tests the Peltzman Effect utilizing a unique dataset that is used to investigate the behavior of Formula One racecar drivers. The race-level dataset was culled from various sources and includes detailed information from a total of 547 Formula One races. A fixed effects model is used to determine whether or not Formula One racecar drivers alter their behavior in response to changes in the conditional probability of a *casualty* given an accident. The empirical estimates support economic theory; Formula One racecar drivers become more reckless as their cars become safer, *ceteris paribus*. Furthermore, the behavioral response of drivers is larger when the analysis is confined to changes in the conditional probability of a *fatality* given an accident.

The second essay utilizes data from the National Youth Survey to reevaluate key conclusions from Fair (1978). This study supports some of Fair's empirical findings; however, the estimates obtained from this research contradict Fair in several key ways. For example, this paper finds that the coefficients of occupation and education are both statistically significant but the signs are opposite to those in Fair (1978). An even more noteworthy contradiction is the negative relationship between years of marriage and infidelity; this suggests that marriage longevity is positively related to that of match quality of the relationship. Also included in these new specifications are independent variables that better control for individual heterogeneity, factors such as general health, race, and alcohol consumption.

This essay presents a simple model to characterize the outcome of a land dispute between two rival parties using a Stackelberg game. This study assumes that opposing parties have access to different technologies for challenging and defending in conflict. Conditions are derived under which territorial conflict between the two parties is less likely to persist indefinitely. Allowing for an exogenous destruction term as in Garfinkel and Skaperdas (2000), it is shown that, when the nature of conflict becomes more destructive, the likelihood of a peaceful outcome, in which the territory's initial possessor deters the challenging party, increases if the initial possessor holds more intrinsic value for the disputed land.

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Dedication

To my maternal grandfather who has shown me the benefits of being curious about things.

CHAPTER 1 - Estimating the Offsetting Effects of Driver Behavior in Response to Safety Regulation: The Case of Formula One Racing

“At the time (the 1960s and 70s) the safety precautions weren't as sophisticated as they are nowadays. The tiniest driving mistake could be lethal.”

Former Formula One Driver, Jacky Ickx

1. Introduction

Traditionally, economists have maintained that drivers will drive more recklessly as auto safety improves, *ceteris paribus*. However, when it comes to observed offsetting behavior that drivers make in response to increased safety, the empirical research conducted by economists has been anything but conclusive. There haven been numerous research papers published that have examined the notion of driver offsetting behavior, but since the evidence has been so mixed in the empirical literature, conditions are conducive for an additional study on the effects that safety regulation has on driver behavior. This research investigates the behavior of Formula One racecar drivers.

The format of the paper is as follows: 2) literature review, 3) Formula One history, 4) model, 5) results, and section 6) concludes.

2. Literature Review

According to Graham and Garber (1984), there are two primary competing theoretical perspectives when investigating the effects of automobile safety regulation. The first viewpoint is that of the rationalists; this is the framework that most economists assume in their analysis. The rationalist theory states that as cars become safer, drivers will become more reckless, *ceteris paribus*.

The second primary viewpoint is that of the behaviorist perspective. This perspective contends that drivers might even ignore the chance of injury from driving a car, “based on the

heuristic that when probabilities drop below some threshold, they are treated as if they are zero.” Likewise, the engineer assumes that driver behavior will not be affected by improvements in safety. The following literature review will primarily focus on the research done from the rationalist perspective as this is the prevailing view of economists, even though the empirical evidence is scant.

The seminal study of the offsetting behavior of drivers was Peltzman (1975). He used economic theory to explain how drivers are expected to change their behavior in response to automobile safety legislation. According to Peltzman (1975), the approach taken by the non-economic safety literature is to use “the probability of the accident as a datum, and seek only to measure how much the probability of surviving an accident is enhanced by a safety-device.” The wave of new safety regulations in the 1960s (spurred by Ralph Nader’s book *Unsafe at Any Speed*), could have changed the incentive to drive recklessly. Peltzman (1975) further argues that “the mandatory installation of safety devices does not by itself change the private demand for safety, but it may change some relevant prices the response to which may mitigate some of the technological promise of these devices.” Accordingly, when Peltzman (1975) uses both time-series and cross-section data, his results provide evidence that auto safety regulation did not affect the highway death rate. His conclusion is that “safety regulation has decreased the risk of death from an accident by more than an unregulated market would have, but drivers have offset this by taking greater accident risk.”

This paper spawned a host of other studies that all attempt to either support or dispel Peltzman’s findings. The literature is quite mixed in its support of his original contribution. Robertson (1977) was the first extension of Peltzman’s original model. He questioned the methodology of the latter when comparing actual death rates post-regulation with the projected death rates in the absence of regulation. Peltzman used pre-regulation data to get these projected death rates. Robertson (1977) tests the predictive power of the Peltzman model, and concludes the “projected rates progressively diverge from the actual rates . . . Therefore, projections . . . would be expected to diverge from actual rates in the absence of regulation.” When Robertson adjusts the original model, the offsetting behavior of drivers seemingly disappears.

Peltzman (1977) replied that the original model was indeed robust to several specifications and that Robertson (1977) ignored the economic theory when using statistical analysis. He also showed that Robertson’s adjustments lack any and all theoretical motivation;

thus, Peltzman concludes that Robertson, in effect, rigged the results in order to disprove the offsetting behavior hypothesis. It should be noted that the data used by both authors is messy due to the aggregate nature of the real-world data.

In another study, Graham and Garber (1984) use the same data set as Peltzman (1975), but they changed the functional form from logarithmic to using the absolute levels of the variables. Once this change was made, a much different conclusion was reached; the resulting estimates from Graham and Garber (1984) show “that regulation *averted* roughly 5,000 casualties between 1966 and 1972, rather than causing about 10,000 deaths as Peltzman’s estimates suggest (Graham and Garber).” Using their own model with a more descriptive set of independent variables, the author’s find that the government mandated safety equipment has saved tens of thousands of lives. However, it is noted that their model did not test for any offsetting driver effects.

Crandall and Graham (1984) use a simultaneous equation model to further explore what can be called the Peltzman Effect. They explain that a primary data concern exists because it is difficult to find an accurate measure for the key independent variable, namely, the degree of crashworthiness required by federal regulation. In order to find a better measure, they employ two different proxy variables for their estimation. The first is the proportion of miles driven by cars built since federal automobile safety regulation began in 1968, while the second proxy is a weighted measure of such miles where the weights reflect estimates of improved occupant protection built into successive post-1965 model cars. The estimates for the two proxies show some offsetting behavior, but not enough to reach the levels that Peltzman showed in his seminal work. However, they admitted that their proxy variables were still not very precise.

Another study that gives indirect evidence of the efficacy of auto safety regulation is Crandall et al. (1984). They show that the implementation of required safety features does not specifically change the average total cost of automobiles. However, the authors note that this finding of insignificance could stem from a poor measure of safety constraint from their model.

In their survey of the automobile safety literature, Lund and O’Neill (1986) claim that the non-economic safety literature has almost uniformly denied the existence of risk compensation; one exception was the Rumar et al. (1976) study that found Swedish equipped studded tires on their autos increased their speed around snow covered turns in the road. Further, they remind us again that post-Peltzman *economic* studies have failed to find offsetting behavior as well. The

literature review concludes by purporting a seemingly behaviorist viewpoint that “people should be encouraged to reduce their risk of injury by supporting effective injury reducing measures.”

Following this literature review, a series of economic studies from the early 1990s found partially offsetting effects while one study concluded that effects were completely offsetting. The following is a description of these studies.

Evans and Graham (1991) use a fixed-effects model to estimate the effects of United States seat-belt regulation. They cite survey data that suggests seat-belt usage went up as state-law required their use; “In all states with such laws, usage rates increased rapidly after the laws became effective, with the average increase being 28% (Evans and Graham).” The authors present a rough estimate when the assumption of no offsetting behavior is made; they described that when belt-use rates increase by 25 to 50 percent and if the seat-belts are 40 to 50 percent effective when occupants are involved in a crash, then seat-belt laws can be expected to lower fatalities by 10 to 25 percent. Their results using sophisticated analysis confirm the back of the envelope calculation. The authors did find some evidence confirming offsetting behavior in that non-occupant fatalities increased when states adopted seat-belt laws. However, the authors contend that “the estimated number of lives lost due to non-occupant collisions . . . is swamped by the lifesaving effects for occupants.” This study upholds the notion that seat-belt laws save lives, at least in the short-run. They added by saying that in the long-run, there might be additional compensatory behavior as drivers might need time to fully adjust their behavior.

A study by Chirinko and Harper (1993) partially supports the conclusions of Peltzman. The paper finds that drivers partially off-set the intended effects of safety regulation. Accident rates were found to increase with safety-legislation and also pedestrian fatalities increased as well; however, in the aggregate, the authors found that the auto safety regulation decreased the total number of fatalities by 16.2 percent (which is much smaller than if there were no offsetting effects). Conversely, Risa (1994) using data from Norway, supported Peltzman’s findings of totally offsetting behavior. She found that there was such a large increase in accidents due to seat-belt regulation, that this legislation actually caused the total number of fatalities to increase. This is the only post-Peltzman study that finds a completely offsetting effect. Meanwhile, Loeb (1995) found that seatbelt laws in Texas reduced injury rates, but the model did not test for any offsetting effects.

In a study that analyzed personal injury loss data from the insurance industry, Hoffer and Millner (1995) find that during the years 1990-1993, autos that were newly equipped with airbags were more expensive to fix after accidents. Using another data set, the same authors also find that “drivers of air-bag-equipped cars initiate an unusually large percentage of such crashes.” They conclude that drivers of cars with air-bags drive more recklessly, *ceteris paribus*.

This concludes a description of studies that use “real-world” accident data to test for offsetting effects. Recently, researchers have begun testing for the effects of safety regulation by turning to a more artificial form of auto-driving, that of racecars. O’Roark and Wood (2004) investigate the effect of restrictor plates on safety in NASCAR. Restrictor plates are a device that limits the speed engines can generate and were designed to reduce the number of serious accidents in races. Using OLS, the authors find that the number of accidents increased when restrictor plates were used; this result is consistent with the offsetting behavior hypothesis. However, when the researchers use an ordered probit model to investigate the effect that restrictor plates had on safety, “there was no systematic evidence that they have led to more driver injuries.” Reducing the speed of the racecars did not seem to decrease the likelihood of driver injury.

Using a more sophisticated approach, Sobel and Nesbit (2007) are able to test directly for offsetting effects in NASCAR. Rather than use a dummy variable approach as O’Rourke and Wood (2004) did to test for the implementation of “safety” features, Sobel and Nesbit used an innovative moving average variable to account for driver’s perception of the conditional probability of being injured in a wreck. Using a fixed effects approach, the authors found that there is an inverse relationship between the conditional probability of being injured and the number of accidents. However, the effects were not completely offsetting.

This paper uses the same methodology as Sobel and Nesbit, but utilizes accident data from a sport that researchers have previously ignored, Formula One racing.

3. The History Formula One Racing

The Formula One World Championship was formed in 1950 in order to bring the world’s best racing teams and drivers to compete in the most respected races. Each subsequent year has continued this tradition that began in 1950. Formula one racing is believed to attract the best

racecar drivers in the world. The majority of races are held in Europe, but individual races have been held on every continent except for Antarctica.

Since speeds often exceed 200 km/hr while racing on asymmetric courses, formula one racing is also one of the most dangerous sports in the world. From the years 1950-1996, there were 54 injuries and 20 deaths in Formula One races. Since the total number of events equaled 597, the number of serious accidents per race is quite significant. Do Formula One drivers take this danger into account when they race or do they potentially ignore the chance of serious injury as the behaviorist community suggest?

In the 1960s, in response to high levels of injuries and deaths per accident, Formula One drivers campaigned to improve the safety of their race cars. Since then, the safety of cars has improved dramatically. The website fltechnical.net provides a comprehensive listing of the safety changes made over the years in Formula One racing. These changes in safety range from better racing helmets to fuel tank safety foam.

Stirling Moss, a driver in the early years of Formula One said, "I would rather lose a race driving fast enough to win it than win one driving slow enough to lose it." This sort of attitude from racecar drivers implies that winning comes before safety. However, social scientists are trained to place more weight on what individuals do in all situations rather than what they say.

This paper intends to answer the following question with a unique data set: do Formula One drivers alter their behavior when racing becomes safer or do they ignore such incentives? This paper is the first attempt to answer this important question.

4. The Model

The most simplified form of the model similar to Peltzman (1975) and Sobel and Nesbit (2007) is:

$$C = A\rho \quad (1)$$

Where C is the number of casualties, A is the number of accidents, and ρ is the conditional probability of casualty given an accident. When safety regulation is implemented that increases automobile safety, the variable ρ will necessarily decrease. Generally when this occurs, the regulatory commission that implemented the change will claim victory. For example, the FIA¹ Deputy Vice President says, “Preventing accidents is not always possible but minimizing the consequences of an accident is fundamental to the FIA institute’s approach.” This quote demonstrates anecdotally that the FIA will focus on making the ρ smaller while at the same time accepting the A term as given. Thus, the FIA might be ignoring the fact that A will increase as ρ decreases; if the former increases by enough, then the number of casualties will actually increase as a result of safer cars.

As in Sobel and Nesbit (2007), taking the total derivative of equation (1) produces:

$$dC = \rho \frac{\partial A}{\partial \rho} d\rho + A d\rho \quad (2)$$

This simplifies to:

$$\frac{dC}{d\rho} = \rho \frac{\partial A}{\partial \rho} + A \quad (3)$$

This equation represents the change of casualties in response to a change in the conditional probability of being injured in an accident. Values for ρ and A are given in the summary statistics in the Appendix and both will obviously be positive. Theory implies that $\frac{\partial A}{\partial \rho} < 0$ and this hypothesis will be tested by using econometric techniques on a Formula One

¹ FIAinstitute.com states, “the objective of the FIA institute is to promote improvements in the safety of motorsport”.

racing data set. If the hypothesis is confirmed, and if the absolute value of $\frac{\partial A}{\partial \rho}$ is large enough, then the “offsetting” behavior of drivers will be large enough to completely reverse the intended consequences of the FIA’s safety regulation.

4. Data and Estimation

The data set was collected from two internet sources. The chief source was Grandprix.com, which is the official supplier of the motorsport database to the FIA. This website has information on each Formula One race since 1950. A supplementary source was fl1dp.com and is formally called the Formula One Database. Information was culled from each race since the records were kept until 1996. Cross-checking the sources revealed that they are consistent with each other. Data were collected from the years 1950-1996 and the race-level data set consists of 537 observations (each race is counted as one observation). The reporting of the data changed after the 1996 season; this is why the dataset does not continue past this year. The season-level data set consists of 46 observations although only 36 of them are of use for reasons discussed below. This data set is able to control for many factors that the street-level data is not able to (for example rain is controlled for); I test how similar drivers on similar tracks respond to incentives. It is now conceivable that *ceteris paribus* relationships of key economic variables can be analyzed.²

The formal econometric model is as follows:

$$Accidents_i = \alpha_1 + \alpha_2 \rho_i + \alpha_3 X + \varepsilon \quad (4)$$

More specifically, the dependent variable is actually the percentage of cars eliminated from the race due to being in an accident.³ For race-level estimation, this variable is computed as follows:

$$Accidents_i = \frac{Quantity_of_accidents_in_race_i}{Quantity_of_cars_in_race_i} \quad (5)$$

² As in Sobel and Nesbit (2007), time subscripts are not used since time is not part of this type of panel regression.

³ Cars leave races for a variety of reasons including accidents, mechanical failure, disqualification due to rules violation, etc. Note: α_2 is equivalent to $\frac{\partial A}{\partial \rho}$.

The independent variable of interest is ρ ; it is a moving average variable computed in the following manner:

$$\rho_i = \left(\frac{\sum_{t=i-1}^{i-n} \text{Casualties}_j}{\sum_{t=i-1}^{i-n} \text{Accidents}_j} \right), \text{ where}^4 \quad (6)$$

$$n = y(1 - y)\left(\frac{z}{E}\right)^2 \quad (7)$$

Where y is the probability of a casualty conditional on being in an accident over all of the observations, z is the standard normal value for a confidence interval (with 95% confidence). E is the maximum allowable error which is equal to 5%.⁵ t chronologically orders the races through time. Essentially, the variable ρ utilizes information from the previous n races over time and serves as a proxy for the safety of automobiles on race day i . Since the first observation of ρ necessarily requires information from the previous 70 races, the dataset is narrowed from 597 to 527 observations, so the earliest observation occurs in the year 1958.

X includes the following control variables: cars per kilometer of track, speed of the fastest lap, a dummy variable for rain, starting position of the winner, number of lead changes, and track. The econometric regressions use a fixed effects approach that control for the individual race-tracks.

Our priors suggest that all of the control variables will be positively related to the dependent variable. The reasoning for these priors follows. Cars per kilometer will be positively related to the number of accidents since a higher density of cars increases the likelihood of incident; this result follows generally for driving in the real-world. Speed will be related positively to the dependent variable because other things equal, faster speeds diminish the reaction time for drivers to avoid threatening situations. Rain is expected to be positive for the same reasoning as the speed variable. Lastly, the number of lead changes will be positively related the accident variable because more lead changes suggest a more competitive race environment that includes an increased number of wheel-to-wheel confrontations.

⁴ Casualties are defined as the sum of all race injuries and fatalities.

⁵ For the primary regression $n=70$.

The ρ variable represents the perceived probability of casualty conditioned on being in an accident.

An anecdotal example sheds light on the rationale of this variable: a retired Formula One driver said the following regarding safety conditions, “If you were a Formula one driver from 1968-1973, chances are that you died.” Since drivers are expected to drive more cautiously when the perceived probability of serious injury is high conditioned on being in an accident, one expects the accident rates over these years to be quite low. This is precisely what the data show. Over the years 1968-1973, accident rates were among the lowest measured in the history of Formula One.⁶ With technological safety advances, accident rates began to climb. Figure 1 provides a nice representation of the correlation between yearly conditional probability of casualty and yearly accident rates. Despite the negative relationship, a fixed effects model can provide further evidence of the causal relationship.

5. Results

The regression results from table 1 show regression results from race-level data from the years 1958-1996. Regressions 2-6 are the results from a fixed effects model where individual track effects are accounted for. In each regression, the robust standard errors are provided, along with the level of statistical significance of each coefficient. The dependent variable for Table 1 is the percentage of cars involved in accidents per race. In all specifications, the coefficient of the independent variable of interest, ρ , is negative and statistically significant at the 1% level. This econometric result confirms the conclusion of the theoretical model; there is evidence of race-car drivers responding to changes in safety, *ceteris paribus*. The size of this variable ranged from -0.46 to -0.60 when using the various FE specifications and all were both statistically and economically significant.

The coefficient rain has the expected sign and is statistically significant. The coefficients of speed, lead change, and starting position were not statistically different from zero. The only unexpected result was that of the density variable; our prior was that the coefficient should be greater zero, but the regression results show a significant negative relationship between the

⁶ Part of the reason why racing was so dangerous before the mid-1970s was that the medical response system was so inefficient.

density of traffic on the track and the number of accidents. One explanation for this result is that drivers will compensate for the dense conditions by driving more “safely”; thus, this could in fact be additional evidence for the compensating behavior of drivers.

The R-squared for the FE specifications range in size from 0.21 to 0.24; the size of the R-squared is standard for this sort of micro-level data.

Table 3 has the same independent variables, but uses season level data instead. The coefficients are all very similar to that of the race-level results. The variable of interest is highly significant in each specification. Since aggregate data is used in Table 3, the R-squared values are expected to be higher. The R-squared ranges from 0.36 to 0.55 which is higher than the race-level data. The results for all the specifications are quite similar to those found by Sobel and Nesbit (2007) in their study of safety in NASCAR. Since there is roughly a 2% chance of dying in a given accident, this unique data set gives us the possibility of investigating how drivers respond to changes in the conditional probability of death. This variable is embedded in ρ , as deaths are a subset of casualties. The correlation between conditional probability of death given an accident and accident rates is shown in Figure 2.

Our priors suggest that the behavioral response will be larger with this new specification, since the average cost of dying is greater than the average cost of being a casualty victim. The results confirm this conjecture. The coefficient of the death variable is roughly twice the size as the coefficient of the ρ variable. Results are found in tables 3 and 4. Except for the death coefficient, the estimates for the controls and the R-squared are economically the same as those from the first specification.

Is the behavior completely offsetting? The answer to this question is no. According to the results, there is only partially offsetting behavior. This means that as the probability of casualty or death decreases, the total number of casualties or deaths will decrease as well. However, the level of casualties is will be lower than predicted by an engineer or the FIA. Estimates use the season-level summary statistics from table 1.

Computation:

$$\text{From before: } \frac{dC}{d\rho} = \rho \frac{\partial A}{\partial \rho} + A$$

The values of ρ and A are 7 and 10 respectively taken from the season-level summary statistics found in appendix 1. The coefficient value of casualty rate from regression 4 in table 3

is used since this regression has the highest R-squared. Now, values are substituted into the above equation:

$$\frac{dC}{d\rho} = 7(-0.54) + 10 = 6.2 > 0$$

Since $\frac{dC}{d\rho} > 0$, there is evidence for partially offsetting behavior of Formula One

drivers in response to increased safety.

6. Conclusion

This research has added to our knowledge of how drivers respond to incentives. Research using street-level data has not proved conclusive in showing offsetting behavior. However, this empirical investigation using a unique Formula One data set shows that drivers exhibit partially offsetting behavior. This result reinforces the work done by Sobel and Nesbit (2007) and gives added empirical evidence in favor of the rationalist school of thought first rigorously proposed by Peltzman (1975).

Further, this is the first paper to show that a change in the conditional probability of driver death has a large impact on driving behavior. This type of analysis was possible because of the high fatality rate in the sport (there was a death in about 4% of races). Also, the response of driving behavior to changes in the death rate appears higher than the response to changes in the casualty rate.

Clearly, the safety changes that were made over the years in the sport have reduced both driver casualties and death, but the magnitude of the lives and limbs that have been saved is certainly smaller than what the FIA would claim. Sobel and Nesbit first proposed that racecar drivers are necessarily more risk loving than the average citizens⁷; however, no research has been done to estimate the risk attitudes of racers compared to others. Ascertaining whether or not racecar drivers respond in the same way to traditional drivers is important for policy considerations. Further research in this field is crucial in order to place more effective safety legislation in regards to everyday driving.

⁷ They cite research that shows theoretically that risk lovers will respond more to a change in driving conditions than will a risk-neutral or risk-averse individual.

Figures and Tables

Figure 1.1- Correlation between accident and casualty rates

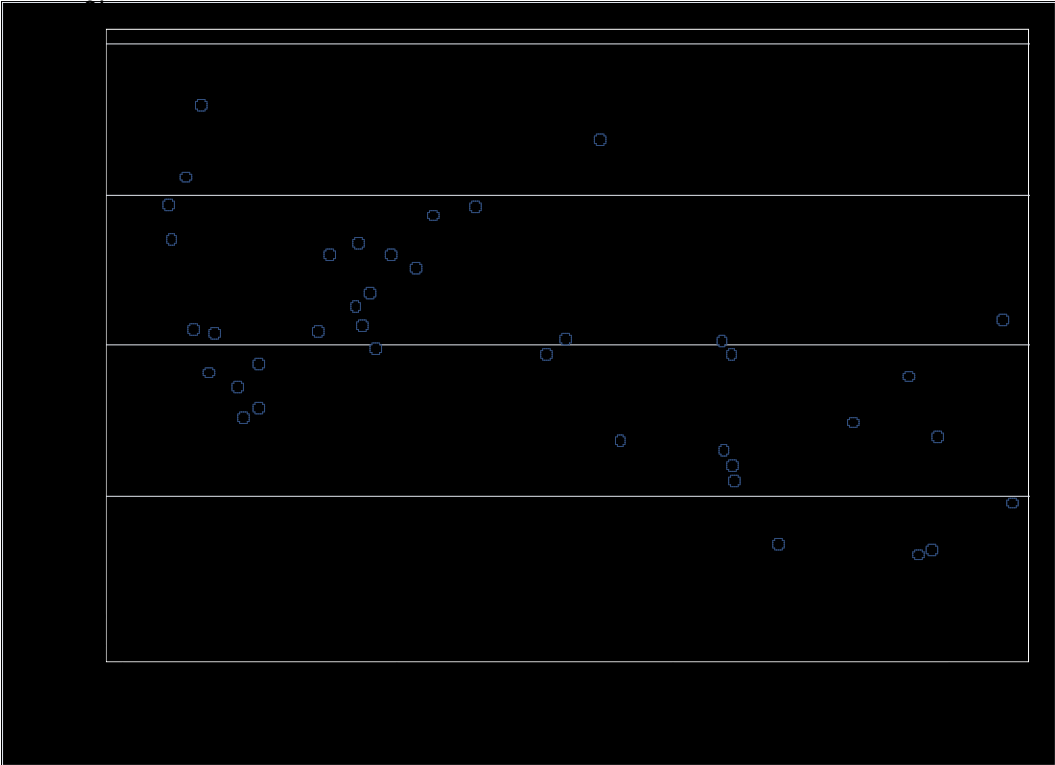


Figure 1.2- Correlation between accident and death rates

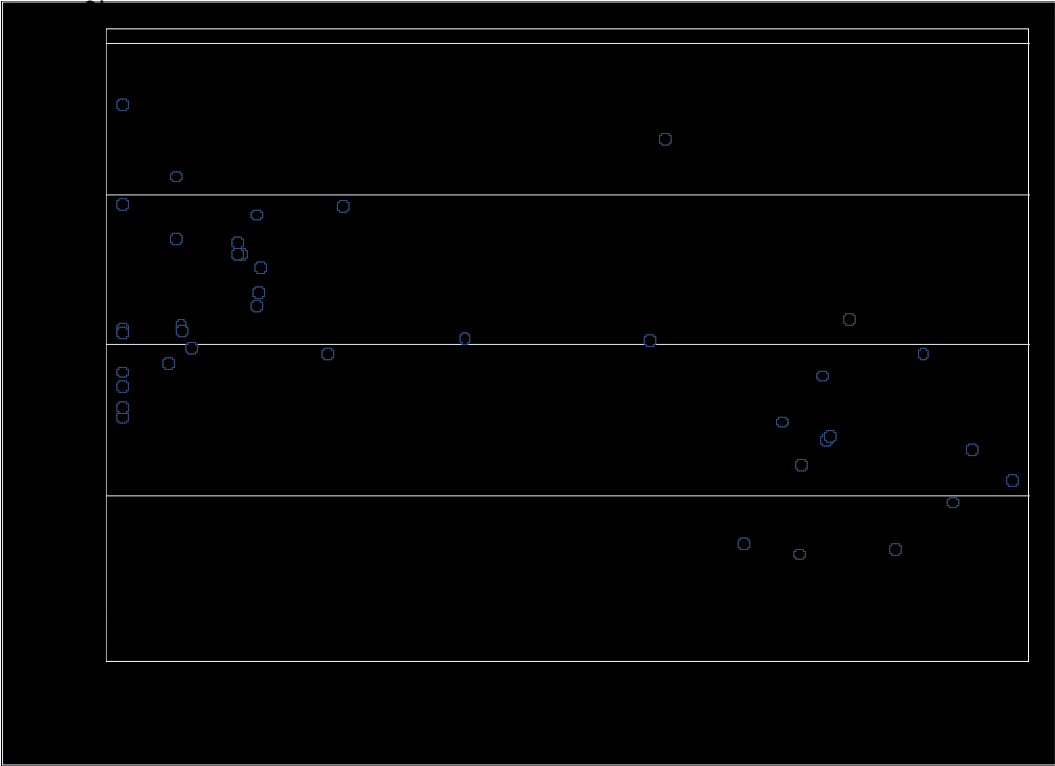


Figure 1.3- Scatter plot of casualty rates and year

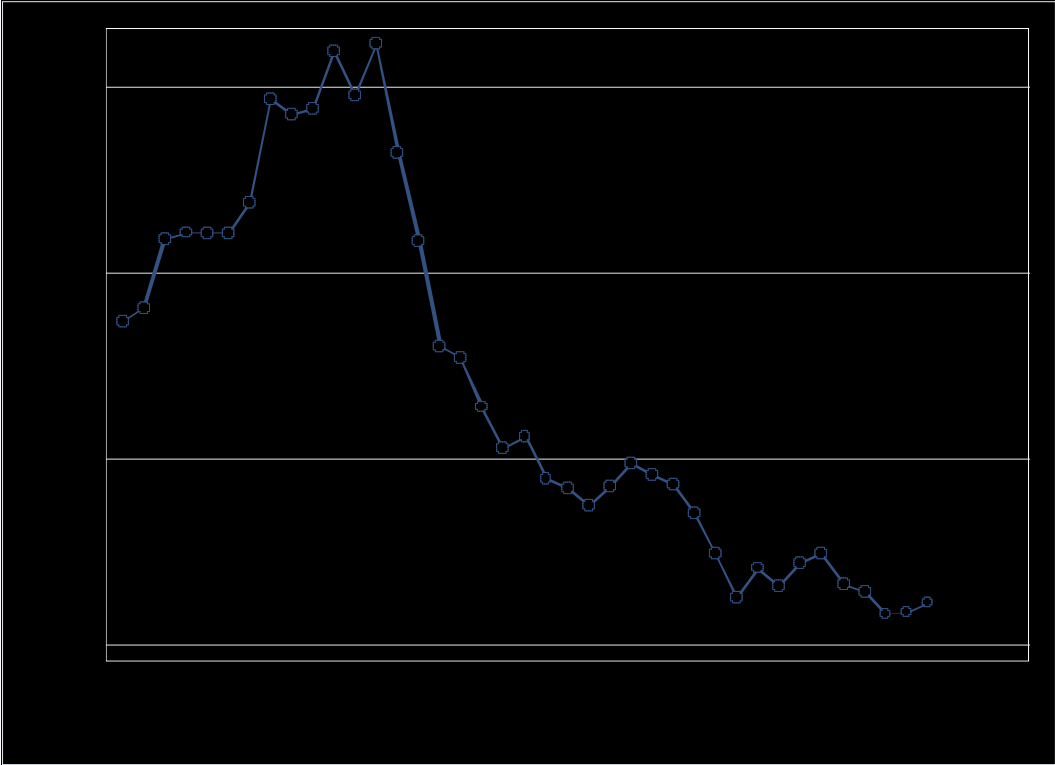


Figure 1.4- Scatter plot of accident rates and year

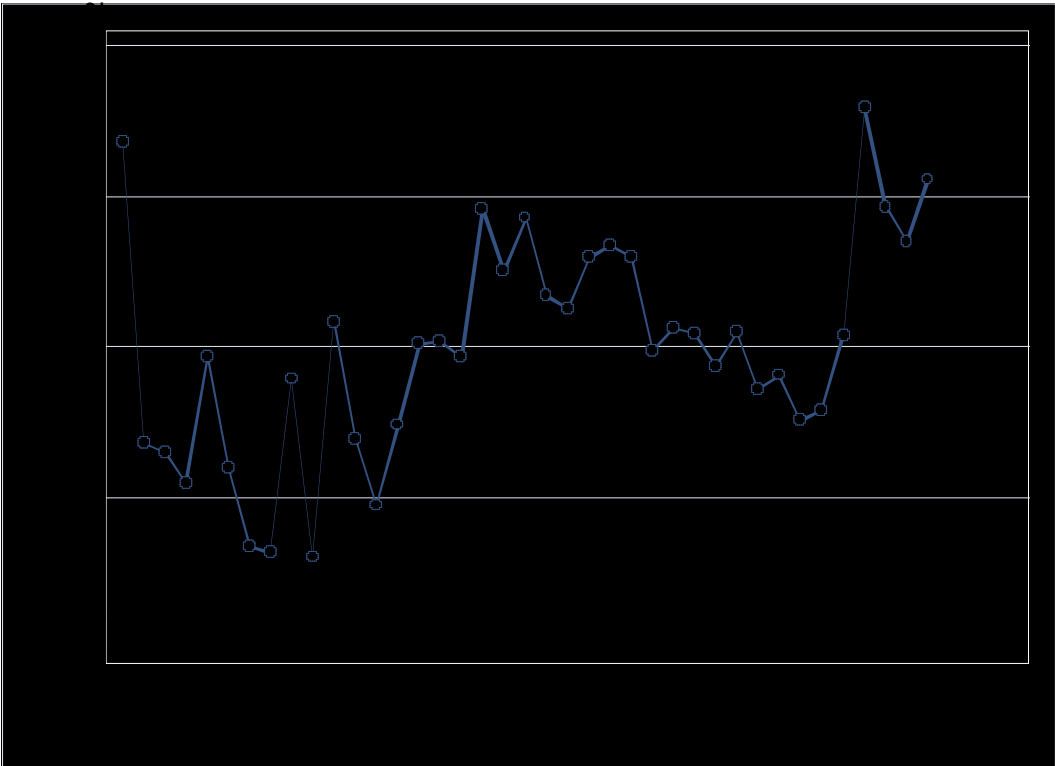


Table 1.1- Summary Statistics for Race Level Data

<i>Variable</i>	<i>Mean</i>	<i>Minimum</i>	<i>Maximum</i>	<i>Std. Deviation</i>
% of cars in an accident	10.3	0	61.9	9.7
Conditional Probability of Casualty	6.2	0.4	17.7	4.7
Conditional Probability of Death	1.8	0	6.9	2.1
Cars per Km	5.6	0.57	11.4	1.9
Speed of fastest lap	187.5	104.3	249.8	29.6
Number of lead changes	2.23	0	40	3.4
Starting Position	3.05	1	22	2.8
Rain	0.14	0	1	0.35

Table 1.2- Summary Statistics for Season Level Data

<i>Variable</i>	<i>Mean</i>	<i>Minimum</i>	<i>Maximum</i>	<i>Std. Deviation</i>
% of cars in an accident	10.0	3	17.9	3.7
Conditional Probability of Casualty	7.0	0.9	16.2	4.9
Conditional Probability of Death	2.3	0	6.4	2.3
Cars per Km	5.4	3.4	8.5	1.2
Speed of fastest lap	186.0	165.5	203.1	8.9
Number of lead changes	2.4	0.8	5.6	1.3
Starting Position	3.1	1.6	5.3	0.9
Rain	0.14	0	0.4	0.1

Table 1.3- OLS Race Level Regressions (fixed effects control for individual race tracks)

<i>Dependent Variable:</i> <i>Accidents_i</i>	(1)	(2)	(3)	(4)	(5)	(6)
Casualty Rate	-0.42*** (5.13)	-0.46*** (3.96)	-0.46*** (4.01)	-0.60*** (4.21)	-0.54*** (3.69)	-0.51*** (3.29)
Rain	---	---	0.05*** (3.12)	0.05*** (3.21)	0.05*** (3.22)	0.05*** (3.19)
Density	---	---	---	-0.01** (2.04)	-0.01** (2.04)	-0.01* (1.89)
Speed	---	---	---	---	0.00 (1.13)	0.00 (0.96)
Starting Position	---	---	---	---	---	0.00 (1.35)
Lead Changes	---	---	---	---	---	-0.00 (0.23)
Fixed Effects	No	Yes	Yes	Yes	Yes	Yes
Constant	0.13*** (18.23)	0.04*** (3.96)	0.00*** (4.01)	0.25*** (8.46)	0.10 (1.47)	0.08 (1.19)
R-Squared	.04	0.21	0.22	0.23	0.23	0.24

All regressions use robust standard errors. *** indicates significance at the 1% level, ** at the 5% level, and * at the 10% level. Regression (1) does not control for track effects.

Table 1.4- OLS Season Level Regressions

<i>Dependent Variable: Rate</i> <i>Yearly_Accident_Rate</i>	(1)	(2)	(3)	(4)
Casualty Rate	-0.45*** (4.49)	-0.46*** (4.93)	-0.61*** (5.07)	-0.54*** (3.57)
Rain	----	0.10*** (3.24)	0.09*** (2.85)	0.08** (2.84)
Density	----	----	-0.01* (1.73)	-0.10*** (3.05)
Speed	----	----	----	0.00 (0.60)
Lead Change	----	----	----	-0.01 (1.51)
Starting Position	----	----	----	0.01* (1.91)
Constant	0.13*** (15.69)	0.12*** (13.89)	0.18*** (5.31)	0.10 (0.65)
R-squared	0.36	0.44	0.48	0.55

All regressions use robust standard errors. *** indicates significance at the 1% level, ** at the 5% level, and * at the 10% level.

Table 1.5- OLS Race Level Regressions (fixed effects control for individual race tracks)

<i>Dependent Variable:</i> <i>Accidents_i</i>	(1)	(2)	(3)	(4)	(5)
Death Rate	-0.90*** (5.20)	-1.00*** (4.15)	-1.00*** (4.16)	-1.31*** (4.46)	-1.14*** (3.36)
Rain	----	----	0.05*** (3.15)	0.05*** (3.25)	0.05*** (3.15)
Density	----	----	----	-0.01** (2.15)	-0.01* (1.94)
Speed	----	----	----	----	0.00 (0.71)
Lead Change	----	----	----	----	-0.00 (0.04)
Starting Position	---	----	----	----	0.00 (1.26)
Track Effects	No	Yes	Yes	Yes	Yes
Constant	0.12*** (20.86)	0.11*** (8.95)	0.15*** (157.13)	0.24*** (8.69)	0.09 (1.24)
R-squared	0.04	0.21	0.22	0.23	0.23

All regressions use robust standard errors. *** indicates significance at the 1% level, ** at the 5% level, and * at the 10% level. Regression (1) does not control for track effects.

Table 1.6- OLS Season Level Regressions

<i>Dependent Variable: Rate</i> <i>Yearly_Accident_Rate</i>	(1)	(2)	(3)	(4)
Death Rate	-0.94*** (4.70)	-0.97*** (5.19)	-1.51*** (6.18)	-1.37*** (3.63)
Rain	----	0.10*** (3.88)	0.10*** (3.53)	0.09*** (3.06)
Density	----	----	-0.01*** (2.94)	-0.01*** (3.17)
Speed	----	----	----	0.00 (0.25)
Lead Changes	----	----	----	-0.00 (0.65)
Starting Position	----	----	----	0.01 (1.31)
Constant	0.12*** (18.19)	0.11*** (14.83)	0.19*** (6.50)	0.14 (0.82)
R-squared	0.35	0.45	0.51	0.54

All regressions use robust standard errors. *** indicates significance at the 1% level, ** at the 5% level, and * at the 10% level.

CHAPTER 2 - The Economics of Cheating: A Reexamination of Fair's Model of Infidelity

1. Introduction and Literature Review

This is a study of the demand for a particular type of leisure good, extramarital affairs. It is a widely held belief by economists that the study of economics can shed light on a variety of social phenomena; therefore, it is not surprising that economists have studied marital infidelity. The seminal work in this area was published in the prestigious Journal of Political Economy by Ray Fair in 1978.

His research presents an economic model that explains the allocation between two types of leisure goods: time spent with the spouse, and time spent with paramour. His motivation for the research is that an individual values a variety of goods in their lives. This notion is hardly new for economists since there is usually more than one type of good in the utility function in classical demand theory. As such, it is not difficult to argue that individuals prefer a variety of leisure activities.

Fair tests the theory by using a modern econometric model by utilizing two distinct datasets. The first dataset is from Psychology Today while the second dataset is from the magazine Redbook. The dependent variable from the PT dataset is the answer to the question, "how often engaged in extramarital sexual intercourse during the past year?" It is a left-censored variable since many observations of the independent variable are zero. This leads Fair to utilize a Tobit model. Independent variables include: sex, age, number of years married, children, how religious, level of education, occupation, and marital happiness.

The chief problem with the data is that they were collected using mail-in surveys so the sample could be biased. Fair concedes that there is a problem with the data and suggests that his results are "good enough to warrant further tests of the model in the future if more data become available." Thus, promising new research in this area is possible by using a better dataset to empirically test key theoretical results.

An extremely rich dataset that includes all of the necessary variables is the National Youth Survey (United States), 1987 Wave VII. The data was collected by using standard probability sampling techniques. Another desirable attribute of the data is that it includes key variables that Fair did not have access to, such as individual wages and spousal income. After a review of the literature, I have concluded that economists after Fair (1978) have only used the Psychology Today and Redbook datasets in conducting their research. For example, Wells (2003) uses the Psychology Today data to support the results from Fair's earlier research. This will be the first paper that utilizes a superior dataset. The goal for this research is to use a Tobit model in order to test the validity of Fair's theory on extramarital affairs.

2. The Theoretical Model

Fair's model includes the following separable utility function:

$$U = U_1 + U_2 \text{ where } U_1 = f(*) \text{ and } U_2 = g(*) \quad (1)$$

Where U_1 is utility gained from the relationship with the spouse whereas U_2 is the utility gained from the relationship with the paramour. The agent is obviously subject to a time and budget constraint. The decision problem for agent i is solved in the standard way by setting up a Lagrangian. The primary objective of this paper is to investigate the effects of exogenous variables on time spent with the paramour.

$$U = f(t_1, t_s, x_1, E_1) + g(t_2, t_p, x_2, E_2) \quad (2)$$

Where:

$$x_1 = x_{1i} + x_{1s}, \quad x_2 = x_{2i} + x_{2s}, \quad \text{and } T = t_1 + t_2 + t_3$$

The budget constraint for agent i is as follows:

$$w(T - t_1 - t_2) + V - p(x_{1i} + x_{2i}) = 0$$

Where, t_1 is time spent with spouse, t_2 is time spent with paramour, t_3 : is time spent working, t_s is time spent by spouse in the relationship, t_p time spent by paramour in the relationship, T is total time, x_1 is total units of the good consumed in the relationship with the spouse, x_2 is total units of the good consumed in the relationship with the paramour, x_{1i} is unit of the good provided by agent i in the relationship with the spouse, x_{2i} is units of the good provided by agent i in the relationship with the paramour, x_{1s} is units of the good provided by the

spouse, x_{2p} is units of the good provided by the paramour, E_1 is taken to include all variables that impact the utility of being with the spouse, E_2 is taken to include all variables that impact the utility of being with the paramour, w is the wage rate, V is non-labor income, p is the price of the goods that agent i supplies.

The problem is solved in the usual way by setting up the Lagrangian:

$$L = U + \lambda[w(T - t_1 - t_2) + V - p(x_{1i} + x_{2i})] \quad (3)$$

The choice variables for agent i are as follows: t_1, t_2, x_1 , and x_2 . The remainder of the variables are taken by the agent as exogenous. This particular model is strong in the sense that the spouse will exhibit the same behavior regardless of the time spent with the paramour. Relaxing this assumption could be an area for future research.

The agent maximizes the Lagrangian subject to the above budget constraint. The theory will be linked to the empirical section by tracing the change of t_2 in response to changes in key exogenous variables. Thus, we are interested in several comparative static partial derivatives:

Table 2.1- Theoretical Predictions

	Derivative	Theoretical Sign
(1.1)		Negative
(1.2)	$\frac{dt_2}{dk_{1i}}$	Ambiguous (but likely positive)
(1.3)		Negative
(1.4)		Ambiguous (depending on income and substitution effects)

3. Data and the Econometric Model

Previously ignored variables were discovered in the National Youth Survey, wave 1987. This dataset includes the response to survey questions in regards to many aspects of

life. All respondents during this wave were between the ages of 21-28; thus, many of the respondents were married. Out of the 1,725 respondents, 553 were married and living with their spouse and will be the relevant population for this study. Why has this dataset been completely ignored in terms of research into extramarital affairs? The most likely reason is that there are no specific questions such as: “Have you had an affair?” The absence of this particular question might well have thrown off previous researchers. However, the survey does ask questions such as: “How often have you slept with your spouse in the past year?” and “How often have you slept with someone that was not your spouse in the past year?”

If all the respondents had been faithful to their spouses, the answers to these questions would be mutually exclusive; however, as expected, many respondents had slept with their spouse *and* somebody else during the previous year, this “somebody else” is what Fair defined as a paramour. Therefore, the definition for engaging in an extramarital affair will be the following:

- a. Currently Married.
- b. Living with the Spouse (i.e. was not separated when engaging with paramour).
- c. Sexual relations (at least once) with a paramour during the past year.

Roughly ten percent of the sample satisfy the above three criteria. The variable chosen to represent the theoretical variable, t_s , will be *Affair_rate*. Survey respondents were asked specifically the rate of sexual encounters with the paramour. Their answers are coded in the following manner found in Table 2.2.

Table 2.2- Description of Dependent Variable

<i>Affair _rate</i>	Value of Dependent Variable
No affair	0
1-3 encounters for the year	1
4-9 encounters for the year	2
Once a month	3
Once every 2 -3 weeks	4
Once every week	5
Two or Three times a week	6
Once a day	7

The dependent variable is quite similar to that of Fair's. It is obvious that *Affair _rate* will be correlated with the theoretical term t_s .

The general form of the full Tobit model is given by:

$$\begin{aligned}
 \textit{Affair_rate} = & \alpha_0 + \alpha_1 \textit{Occupation} + \alpha_2 \textit{Education} + \alpha_3 \textit{Spouse_Occupation} + \alpha_4 \textit{Marital_Satisfaction} \\
 & + \alpha_5 \textit{Kids} + \alpha_6 \textit{Religiousness} + \alpha_7 \textit{Male} + \alpha_8 \textit{Years_Married} + \alpha_9 \textit{Age} + \varepsilon
 \end{aligned}$$

Obviously, since measures of occupation were needed for many of the regressions, non-employed individuals were necessarily removed from the sample.⁸ The above variables will now be described.

Occupation was derived from the Hollingshead index in reverse order. Essentially, the *Occupation* variable measures social status from 1-7 with a 7 being the highest social status possible (see Table 2.5 for a description). This measure is positively correlated with education and Fair hypothesized that it was also positively correlated with wages. The expected sign of the coefficient α_1 is therefore ambiguous.

As in Fair, *Education* is equal to 9 if the individual was a high school dropout, 12 if they only completed high school, 14 if they did some college work, 16 if they graduated with a

⁸ This will reduce the relevant sample size to 434.

college degree, and 17 if they did some post-graduate work. This variable is also correlated with wages so the expected coefficient of *Education* is also ambiguous.

Spouse_Occupation is similar to that of *Occupation*, the only difference is that it measures the socio-economic status of the respondent's spouse (only one regression includes this variable). The coefficient for this variable is expected to be negative.

The variable *Spouse_Satisfaction* was taken from a list of six questions that ranged from "How satisfied are you with your spouse?" to "How much do you have in common with your spouse?" Each answer ranged from 1-5, with the value of 5 rating the spouse in the most favorable way. The six measures were summed and divided by six in order to obtain an average. This hopefully serves as a more accurate measure of overall satisfaction in comparison with the answer to a single question. Obviously, the coefficient of *Spouse_satisfaction* is expected to be negative since the variable is positively correlated with E_1 .

Kids is a dummy variable equal to one when the respondent reported having at least one child and the coefficient of this variable is also expected to be negative.

The variable *religiousness* is used to measure how religious an individual is. Each respondent answered the following two questions. 1) "During the past year, how often did you attend religious services?" An answer of 5 indicates the individual attended a religious service several times a week. 2) "How important has religion been in your life?" An answer 5 indicates that religion is very important to them. The average of the answers to the above questions is used for the variable, *religiousness*. The coefficient of *religiousness* is expected to be negative since a highly religiousness individual will presumably derive less utility from ending the marriage, *ceteris paribus*. *Male* is a dummy variable and is equal to one when the respondent reported being a male. The sign of this coefficient is ambiguous using Fair's model.

The *yearsmarried* variable is calculated as the number of years since marriage for the respondent. This is perhaps the most controversial variable in Fair's original article; he hypothesizes that the coefficient of *yearsmarried*, α_8 , will be *positive*. His explanation is that the longer an individual is married and remains monogamous, the more the utility he/she will get from introducing "variety" into life. This is analogous to saying that the more years somebody only eats vanilla ice cream, the utility they receive from trying a different flavor will necessarily increase. An alternative explanation is that marriage longevity will be negatively related with the

number of affairs since it is a signal of match quality. Fair’s findings support his own hypothesis that the coefficient of this variable to be positive. However, Li and Racine (2004) using non-parametric techniques, find that the number of years married is simply not a predictor of having an extramarital affair. In order to correctly identify how long individuals have been married, those that describe themselves as remarried are necessarily dropped from this data set.

Table 2.3- Expected correlation between theoretical and empirical exogenous variables

<i>Theoretical Variable</i>	<i>Correlated With (Sign)</i>
Occupation	w (positive)
Education	w (positive)
Spouse Occupation	x_{1s} (positive)
Marital Happiness	E_1 (positive)
Age	None
Years Married	E_1 (ambiguous)
Children	E_1 (positive)
Religiousness	E_2 (negative)
Male	None

4. Results

Since the age group of the National Youth Survey was quite homogenous when compared to the Psychology Today and Redbook surveys that Fair utilized, the relevance of including an age variable in the regression was not immediately clear. Table A.2 in the appendix, includes the regressions with and without the age variable. Clearly, the results indicate that age still matters even though the NYS dataset only includes individuals in their twenties. This result is surprising since the sexual functioning of adults in their twenties is seemingly quite constant.

The similarities of the replication and Fair’s study are numerous. First, the marital happiness coefficient is identical in sign to the original study and also matches the theory. Also

in agreement is the degree of religiosity; these coefficients are statistically significant and negative as theory predicts. These results hold for each of the regressions in this paper.

There are some disagreements across studies, however. First, the male variable was larger and much more significant across most of my regressions than it was in Fair's paper. It is well-documented that men cheat on average more than women, and my estimations provide support that this social phenomenon holds even when controlling for sundry other factors. However, if more factors are controlled for, the coefficient might conceivably grow smaller and less significant.

Even more troubling is the disagreement between occupational status and educational attainment. Both should theoretically have the same sign (since they are both positively correlated with the wage rate); however, this is not the case as seen in table A.2. Even more troubling is the fact that Fair and this study are in complete disagreement as to the signs of the coefficients; for example, occupational status is negative with the NYS data and positive in Fair's study. Immediate economic explanations for the signs of these variables are not readily available.

The length of marriage also contradicts Fair's research. He found that years married will be positively correlated with the dependent variable. In the estimation of the NYS data, the coefficient of this variable is negative and is significant at the one percent level in most specifications. This is a very important finding since the NYS data was collected using statistically valid sampling techniques while Fair's data was collected from mail-in surveys. Thus, perhaps it is likely the Fair data previously used could have been biased in some way.

Table 2.4- A Comparison of Empirical Results

Variable	NYS Results	Fair's Results	Empirical Agreement
Occupation	Negative	Positive	No
Education	Positive	Negative	No
Marital Satisfaction	Negative	Negative	Yes
Age	Negative (statistically insignificant)	Negative	Yes
Kids	Negative	Negative	Yes
Religion	Negative	Negative	Yes
Male	Positive	Positive (statistically insignificant)	Yes
Years Married	Negative	Positive	No

The NYS dataset provides two variables that were not available to Fair, wages and spousal income. Wage is one of the most crucial variables of his theoretical model, but as seen previously, the proxy variables for wage are not consistent with each other. Thus, having a true measure for wage is conceivably a large contribution to the literature.

The Tobit model is specified as follows:

$$Affair_rate = \beta_0 + \beta_1 wage + \beta_2 SpouseIncome + \theta X + \varepsilon$$

Where *wage* is the respondent's reported hourly wage rate in at their primary job during 1986 (reported in 1986 dollars). *SpouseIncome* is the respondent's answer to the total amount of income earned by their spouses in 1986. *X* is a matrix of control variables that is similar to the controls used in the regressions during the previous section.

The results of the regressions found in table A.3 are a better representation of Fair's ideal variables. These key variables are wages, spousal income, and spousal occupation. The theoretical prediction of the wage coefficient is ambiguous according to Fair's model. Meanwhile, the coefficients of spousal income and spousal occupation are expected to be negative since there is a likely positive relationship with the theoretical value, E_1 . Interestingly, all of these variables are statistically insignificant as found in table A.3.

Including wages does not alter the signs or magnitude of the other coefficients and is not different from zero. Adding this theoretically important variable does not add much to the

empirical investigation. The same is true for spousal income and spousal occupation. Additionally, the Pseudo-R²s are smaller than those in the first set of regressions

The signs and magnitude of the variables in the X matrix are very robust to model specification. So in light of these findings, perhaps alternative theoretical and empirical models should be considered in future studies of marital infidelity.

5. Conclusion

Fair's (1978) model of an individual's decision to "betray" their spouse describes marital happiness as one of the key exogenous variables that will affect one's decision to "cheat." Fair describes the value of marital happiness as having a causal effect on the amount of cheating. The results from this research confirm this result and others such as degree of religiousness.

However, the empirical estimates of this study contradict Fair's study in several key ways. For example, this paper finds that the coefficients of occupation and education are both statistically significant but the signs are the opposite of those in the original study by Fair. Even more noteworthy is the negative relationship between years of marriage and infidelity; this result suggests that marriage longevity is positively related to that of match quality of the relationship. Fair had suggested that a positive relationship is expected between marriage longevity and infidelity since the marginal utility of cheating will increase the longer one remains monogamous. Also, payout from divorce settlement increases with length of marriage.

As stated before, it is certain from this and former research that marital satisfaction is negatively related with the number of affairs. However, it is not clear whether individuals are having affairs because they are unhappy with their spouse, unhappy in general with their lives, or a combination of the two. This paper only tested for the former; which can be called the marital satisfaction effect.

Sociologists, such as Glenn and Weaver (1981), contend that marital happiness is positively correlated with global/overall happiness. However, there are many other determinants that also influence an individual's global happiness such as health. One key question concerns what factors of happiness will be related to the decision to have an extramarital affair. Intuitively, marital happiness is an easy choice as a factor that will be associated with an individual's decision to have an affair.

However, it might not be immediately clear whether or not other determinants of well-being will be positively or negatively related with the decision to cheat. For a factor such as general health, it is quite conceivable that this will have a negative effect on the decision to

cheat⁹. For example, Halpern et al. (1999) found that young women with higher body fat counts were less likely to date. Thus, unhappiness as a result of poor health might decrease the likelihood of cheating.

It is likely that the previous literature regarding extramarital affairs has not examined data sources rich enough to fully address the complexities of the situation. A natural extension from this research is to find variables that can account for heterogeneity across individuals, particularly concerning characteristics that might be correlated with engaging in extramarital affairs.

⁹ Hence, if an individual is unhappy because they are overweight, we might expect them to be less eager to cheat because it might be more difficult for them to go on a date, *ceteris paribus*.

Tables

Table 2.5- Summary Statistics

<i>Variable</i>	<i>Observations</i>	<i>Mean</i>	<i>Standard Deviation</i>
Occupation	434	3.59	1.52
Education	434	13.06	2.01
Wage	434	7.40	4.01
Spouse Occupation	386	3.52	1.55
Marital Satisfaction	434	4.21	0.52
Kids	434	0.62	0.49
Religion	434	3.09	1.13
Male	434	0.49	0.50
Age	434	24.29	1.89
Spouse Income (in thousands)	429	13.98	10.77
Years Married	434	3.79	2.29
Affair rate	434	0.29	1.04

Table 2.6- Hollingshead Index

Code	Occupation
1	Unskilled
2	Machine operators, semi-skilled
3	Skilled manual
4	Clerical and sales, technician, etc.
5	Administrative personnel, etc.
6	Business manager, etc.
7	Higher executive, major professional, etc.

Table 2.7- A Replication of Fair's Estimation by Utilizing NYS Data

<i>Variable</i>	<i>(1)</i>	<i>(2)</i>	<i>(3)</i>
Constant	5.91** (1.73)	10.35** (1.88)	8.72 (1.38)
Occupation	-0.49** (1.79)	-0.45** (1.67)	-0.40 (1.32)
Education	0.19 (1.01)	0.25 (1.25)	0.32 (1.41)
Spouse Occupation	-----	-----	-0.24 (0.79)
Marital Satisfaction	-1.76*** (2.72)	-1.78*** (2.76)	-1.83** (2.40)
Kids	-0.46 (0.57)	-0.45 (0.56)	-0.39 (0.43)
Religiousness	-1.14*** (3.11)	-1.13*** (3.09)	-1.13*** (2.76)
Male	1.12* (1.52)	1.21* (1.63)	1.23* (1.49)
Years Married	-0.50*** (2.78)	-0.42** (2.15)	-0.55** (2.37)
Age	-----	-0.23 (1.04)	-0.16 (0.63)
Observations	434	434	381
LR- Chi squared	42.45	43.54	37.89
Pseudo -R2	0.0851	0.0873	0.0872

t-statistics are in parenthesis. *** indicates statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

Table 2.8- Regressions that Include More of Fair's Ideal Variables

<i>Variable</i>	(1)	(2)	(3)
Wage	-0.04 (0.43)	-0.02 (0.18)	-0.04 (0.29)
Marital Satisfaction	-1.70*** (2.62)	-1.71*** (2.59)	-1.70** (2.18)
Kids	-0.44 (0.55)	-0.52 (0.63)	-0.53 (0.59)
Religiousness	-1.11*** (3.07)	-1.11*** (3.03)	-1.10*** (2.65)
Male	1.31* (1.72)	1.09 (1.19)	1.18 (1.19)
Years Married	-0.43** (2.22)	-0.40** (2.07)	-0.53** (2.23)
Age	-0.20 (0.96)	-0.27 (1.19)	-0.16 (0.62)
Spouse Income	-----	-0.012 (0.28)	-0.009 (0.17)
Spouse Occupation	-----	-----	-0.20 (0.63)
Constant	11.26** (2.01)	12.84** (2.20)	11.23* (1.67)
Observations	434	424	371
LR- Chi squared	40.53	39.40	33.88
Pseudo-R2	0.0813	0.0805	0.0796

t-statistics are in parenthesis. **** indicates statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

CHAPTER 3 - The Fate of Disputed Territories: An Economic Analysis

1. Introduction

As evidenced by our ever-changing political maps, situations often arise in which two parties or groups fight over a disputed territory. A party can value land not only for economic reasons, but also on intrinsic grounds, as in the case of India and Pakistan's dispute over the border regions Jammu and Kashmir. It is easy to see how competing parties might prize a piece of land that bears cultural significance or one that is rich in some scarce resource. However, attempts by a challenger to take the land from its possessor are costly. Under what circumstances, then, will the challenger attack? To what degree does the defending party arm itself in preparation for possible attack? Lastly, when might a dispute end and peace be everlasting?

Social scientists have observed that territorial disputes are the primary cause of war (Goetz and Diehl 1992; Vasquez 1993; Kocs 1995; Forsberg 1996; Huth 1996). Although the specific roots of conflict over territory vary from one land to another, they are directly related to a territory's economic value, nationalist value, or both (Huth 1996; Wiegand 2004). Moreover, it has been noted that territorial disputes vary significantly with respect to duration and outcome, suggesting that many factors characterize the fate of a disputed territory (Collier and Hoeffler 1998; Collier, Hoeffler, and Soderbom 2004; Fearon 2004; Hegre 2004).

Focusing on territorial disputes, we present a simple game-theoretic model of conflict to identify possible factors that determine the effective deterrence of a challenger by the territory's possessor. Methodologically, we follow Gershenson and Grossman (2000) and use a one-period repeated game where each party is myopic.¹ Although their model is one-period (or static) in nature, Gershenson and Grossman explain well why civil conflict may be never-ending in a period-to-period (or dynamic) framework of perpetual conflict. However, our investigation of territorial conflict departs from their analysis of civil conflict in two important aspects. These deviations allow us to offer a more complete analysis of territorial conflict.

First, Gershenson and Grossman use only a *status* parameter to characterize relative military spending effectiveness of each party. Hence, a change in dominant party implies an inversion of the two parties' relative military spending effectiveness. As the paper states, “[t]his specification implies that both groups have access to the same technologies for challenging political dominance” (Gershenson and Grossman, 2000, p. 811). We find this assumption too restrictive in the case of (civil or non-civil) territorial dispute. If cultural and religious differences between opposing parties can persist, why cannot differences in level of military human capital, for instance, do the same? In the case of the United States Civil War, the talent of the Union Army generals is generally recognized as inferior to that of the Confederacy (Wells, 1922). When the Union recaptured the Confederacy, did the former party instantly enjoy the advantage of a superior set of generals by virtue of the fact that it had won? Obviously, it did not. After victory or defeat, therefore, it is important to allow for the possibility that two parties are innately different in terms of military effectiveness.² By including an *identity* parameter that characterizes relative positional/strategic effectiveness, in addition to a status parameter that captures relative military effectiveness in the disputed territory, our model can address situations of territorial dispute. The inclusion of this identity parameter allows us to conclude that territorial conflict between two parties is less likely to persist indefinitely (with land possession alternating stochastically) when parties have access to *different* technologies for challenging political dominance in a region.

Second, we consider how destruction of economic resources affects the outcome of a conflict in land dispute. Our model follows Gershenson and Grossman (2000) and Garfinkel and Skaperdas (2000) in employing an exogenous destruction term that is common to each party.³ Unlike Gershenson and Grossman, who implicitly set their exogenous destruction term equal to zero, we allow for destruction in a given conflict. Relaxing this assumption permits us to examine the comparative static effects of exogenous changes in destruction on causes of war or peace. The model suggests that, as the nature of conflict becomes more destructive, the likelihood of a peaceful outcome improves given that the challenging party has relatively less intrinsic value for the land.⁴ Also, if war is to end, it may end more quickly (and will never end less quickly) as the nature of war becomes more destructive. Lastly, assuming that war is exogenously destructive creates the possibility that a challenging party invades a territory but later withdraws due to reduced economic incentives to continue the attack.⁵

Additionally, so as not to allow our model's applicability to be bound by political definitions, we broadly define the term *disputed territory* as any land valued by more than one party. This definition allows us to consider the more general question of “Why are some territories not attacked?”

The remainder of this essay is organized as follows. Section 2 develops a simple Stackelberg framework of territorial dispute to characterize strategic interactions between two rival parties. In the section, we discuss several scenarios of conflict and deterrence and derive the conditions under which war is endless in the absence of exogenous shock. Section 3 concludes.

2. The Model

Following Gershenson and Grossman (2000), we adopt a “myopic” framework of conflict to characterize the outcome of territorial disputes from one period to another.⁶ We consider a two-party model in which Party A possesses a disputed territory initially and is prepared to incur costs to maintain possession, as Party B might attempt to take the land by force. Consistent with the research questions offered in our opening paragraph, we would like to find conditions under which Party B fights for the land. If fighting commences, we wish to determine under what circumstances it ceases. To this end, we examine the following five collectively exhaustive scenarios:

Scenario 1: Party A effectively deters Party B (there is no war).

Scenario 2: Party A eventually deters Party B (there is war, but Party A deters Party B without the land changing hands).

Scenario 3: Party B fights, takes the land, and immediately deters Party A.

Scenario 4: Party B fights, takes the land, and eventually deters Party A.

Scenario 5: Subsequent conflict (including the case where war is endless).

Should disagreement over the disputed region lead to war (i.e., armed confrontation) between A and B in period $(i + j)$, each party is assumed to have a realized probability of victory (or contest success function) as follows:

$$P_{A,i+j} = \frac{\omega l G_{A,i+j}}{\omega l G_{A,i+j} + \mu f G_{B,i+j}} \quad \text{and} \quad P_{B,i+j} = \frac{\mu f G_{B,i+j}}{\omega l G_{A,i+j} + \mu f G_{B,i+j}}, \quad (1)$$

Party A is the leader, ⁷ where

the number of periods over which fighting occurs;

ψ the number of periods over which there is no armed confrontation;

the military effectiveness of Party A, an identity parameter;

the military effectiveness of Party B, an identity parameter

positional or strategic effectiveness of the defender in the disputed region, a status parameter;

positional or strategic effectiveness of the challenger in the disputed region, a status

parameter;

units of military goods Party A has obtained to defend the disputed land;

units of military goods Party B has obtained to challenge for the disputed land.

It is easy to verify that the probability contest functions have the following properties:

$$\frac{\partial P_{B,i+j}}{\partial G_{B,i+j}} > 0,$$

Note that derivative signs involving ψ and μ will differ as the land changes possession. The contest success functions (CSFs) in (1) can be rewritten as

$$\text{and} \tag{1}$$

where μ is a ratio comparing the “overall” (i.e., military and strategic) effectiveness of

Party B in attacking the disputed territory to that of Party A in defending the disputed territory.

In addressing the disputed land situation, each party chooses to purchase a number of guns that maximizes its expected payoff. If Parties A and B are fighting in period t , their payoffs in the next period are given respectively as

$$\tag{2a}$$

$$\tag{2b}$$

Equations (2a) and (2b) can be explained as follows: $U_{T,i+j+1}$ is Party T's expected utility in time period $i+j+1$ (where $T = (A, B)$, $(i+j) \in N^*$),⁹ $E_{T,i+j}$ is Party T's *flow* of endowment in period i , V_T is the amount of intrinsic value Party T places on holding the land,¹⁰ $(1-\delta)$ represents the destruction rate of the land's economic value with each period of fighting ($\delta \in (0,1)$), and W is the initial (pre-war) economic value associated with holding the land in a period such that the product $\delta^{i+1}W$ is the economic value associated with holding the land in period $i+j+1$, α is Party A's unit cost of obtaining a military good and allocating it to the disputed territory, and β is Party B's unit cost of obtaining a military good and allocating it to the disputed territory. Additionally, the model assumes full depreciation of military goods with each period of fighting.

The specification of this model allows for various differences between the two rival parties, as well as differences in the nature of the disputed land. We first note that a party's probability of victory is a function of both that party's military effectiveness and whether the party is defending or attacking. The identity parameters ω and μ allow for the possibility that military effectiveness differs across parties ($\omega \neq \mu$). For example, in 1940, invading German forces used superior blitzkrieg tactics to overwhelm Allied forces in France ($\omega < \mu$) despite the fact that military resources between the two sides were roughly equal (Bloch, 1940). Unequal military effectiveness across contending parties was also observed during the Vietnam War-fought between a U.S./South Vietnam coalition and communist North Vietnam. The U.S. coalition had larger and more powerful guns. However, this did not clinch victory in part because of an inefficient use of military resources. Examples of military ineffectiveness by the U.S. led coalition are listed as follows: professional hubris, *excessive* use of firepower, lavish base camps, hurtful personnel rotation policies, and corruption in the officer corps. The North Vietnamese used guerrilla war tactics and were relatively more effective even while using inferior military technology (Record, 1996). Clearly, this example emphasizes the fact that military effectiveness *can* differ across parties. In this case, the North Vietnam army used a given unit of weaponry more effectively than did the U.S./South Vietnam coalition.

The defending party has a positional or strategic advantage shown by ℓ relative to f . In the model, we assume that $\ell \geq f$. In other words, *ceteris paribus*, it is never easier to capture a land than to successfully defend it. Although the Texans were defeated, the Battle of the Alamo provides a clear example of how positional advantage can swing an additional benefit to the incumbent party. In this case, the Texans held possession of the Alamo until Mexico began its assault. Santa Anna attacked the Alamo with a roughly nine-to-one advantage in number of troops. However, the Texans enjoyed higher elevation and were thus able to fire cannon shot down onto the invaders, greatly disorienting their opponents. When the smoke settled, there were triple the number of casualties among Santa Anna's men as among the Texans. Without any positional advantage for the incumbent party, it is clear that Mexico would have had a much easier task in destroying the small band of men (Proctor, 1986).

Two parties may also incur different costs in obtaining arms and delivering them to the disputed territory. The cost parameters α and β could differ on account of an ally to one party subsidizing that party's gun purchases, as the United States does Israel. In this model, exogenous third parties can play decisive roles in how conflicts resolve. "Allies" of either the attacking or defending party can increase military effectiveness or decrease the price of weaponry (Siqueira, 2003). Such changes can swing power diametrically, as evidenced by the U.S. intervention in Cuba during the Spanish American War.¹¹

One party might value a disputed land for economic gains. Saddam Hussein, for instance, took control of Kuwait in 1990 to increase Iraq's wealth (Deese, 2005). On the other hand, a party might also place a subjectively determined intrinsic value on a disputed territory. In the same conflict, Kuwait intrinsically valued the ability to self-rule, something they could regain through control of the disputed territory. The above model considers the possibility of both types of valuation, as the 1990 attack on Kuwait suggests it should. Note in the model's structure that, in the absence of an exogenous shock, the intrinsic value a party places on holding the territory remains constant over the course of a conflict, whereas the economic value of holding the territory declines at a rate of $(1 - \delta)$ per period. Our model recognizes that war is physically destructive. The value of land where war is fought will not increase, but rather diminish, as a result of war.

Scenario 1: Party A effectively deters Party B (there is no war)

Beginning the analysis with Scenario 1, we examine the condition under which Party A (the territory's defender) effectively deters Party B (the challenger), i.e., there is a “peaceful outcome” or no war. We assume that Party A is a leader and Party B is a follower in a Stackelberg game.¹² Consistent with backward induction, we first examine Party B's optimal decision on arming.

Starting from the initial period when $(i + j) = 0$, the objective of Party B is to choose $G_{B,0}$ that maximizes its expected payoff in the next period $U_{B,1}$ (see (2b)). The Kuhn-Tucker condition for Party B is:¹³

$$\frac{\partial U_{B,1}}{\partial G_{B,0}} < 0, \tag{3}$$

If $G_{B,0} = 0$. It follows that

$$\frac{\partial \hat{G}_{A,0}}{\partial V_B} > 0 \quad \text{when} \quad \frac{\partial U_{B,1}}{\partial G_{B,0}} = 0 \quad \text{and} \quad \psi G_{A,0} (V_B + \delta W) - \beta \leq 0. \tag{4}$$

Equation (4) indicates that Party B finds it optimal not to waste resources in challenging Party A for the disputed land if A's arming initially exceeds the critical level of

Equation (4) is therefore a sufficient condition for Party A to effectively deter Party B. It is easy to verify the following comparative statics:

$$\frac{\partial \hat{G}_{A,0}}{\partial \psi} > 0,$$

Thus, it is more likely that Party B is deterred (i.e., it is more likely that Party A's military defense allocation satisfies the deterrence condition), when (i) Party B's intrinsic value for the disputed territory falls, (ii) the territory's depreciable economic goods lose value more quickly, (iii) the total amount of economic value in the territory falls, (iv) Party B's military effectiveness as challenger falls compared to that of Party A as defender, or (v) Party B's unit cost of arming rises, *ceteris paribus*.

Even if there is peace between the competing parties initially, exogenous changes to parametric values can lead to war. Examples of peace off-setting exogenous shocks might be the

rise of a more capable leader who is able to improve Party B's military effectiveness, the rise of a political party, political leader, or ideological movement which causes Party B to place more intrinsic value on the land, the improvement of Party B's military transportation infrastructure, or Party B's acquisition of an arms rich ally. Conversely, shocks that adversely affect Party A's parameters can also lead to Party B declaring war.

Whenever $G_{A,0} < \hat{G}_{A,0}$, Party A is not allocating enough resources to military defense to effectively deter the opposition and Party B finds it optimal to choose a positive offensive allocation. In this case, war will occur.

If Party B's initial level of arming is positive ($G_{B,0} > 0$), then B has a positive probability of defeating the initial leader of the territory. Specifically, Party B's optimal arming in period $(i + j)$, in which a positive amount of $G_{B,i+j}$ maximizes its expected payoff (see $U_{B,i+j+1}$ in (2b)), should satisfy the following necessary condition:

$$\frac{\partial U_{B,i+j+1}}{\partial G_{B,i+j}} = \frac{\psi G_{A,i+j}}{(G_{A,i+j} + \psi G_{B,i+j})^2} (V_B + \delta^{i+1}W) - \beta = 0.$$

Solving for $G_{B,i+j}$ yields

$$G_{B,i+j} = \sqrt{\frac{G_{A,i+j} (V_B + \delta^{i+1}W)}{\psi\beta}} - \frac{G_{A,i+j}}{\psi}, \quad (5)$$

which defines Party B's reaction function of arming.

Party A as the Stackelberg leader chooses a level of arming $G_{A,i+j}$ that maximizes its expected payoff $U_{A,i+j+1} = E_{A,i+j} + \frac{G_{A,i+j}}{G_{A,i+j} + \psi G_{B,i+j}} (V_A + \delta^{i+1}W) - \alpha G_{A,i+j}$, where $G_{B,i+j}$ is given by the reaction function in (5). Party A's optimal arming $G_{A,i+j}$ should satisfy the following necessary condition:

$$\frac{\partial U_{A,i+j+1}}{\partial G_{A,i+j}} = \frac{(V_A + \delta^{i+1}W)}{(G_{A,i+j} + \psi G_{B,i+j})^2} \left[(G_{A,i+j} + \psi G_{B,i+j}) - G_{A,i+j} \left(1 + \psi \frac{\partial G_{B,i+j}}{\partial G_{A,i+j}} \right) \right] - \alpha = 0. \quad (6)$$

Using (5) and (6) to solve for the Stackelberg equilibrium levels of $G_{A,i+j}$ and $G_{B,i+j}$, we have

$$G_{A,i+j}^* = \frac{\beta (V_A + \delta^{i+1}W)^2}{4\psi\alpha^2 (V_B + \delta^{i+1}W)} > 0 \quad (7a)$$

$$G_{B,i+j}^* = \frac{(V_A + \delta^{i+1}W) [2\psi\alpha (V_B + \delta^{i+1}W) - \beta (V_A + \delta^{i+1}W)]}{(2\psi\alpha)^2 (V_B + \delta^{i+1}W)}. \quad (7b)$$

From (7b), it follows that the necessary condition for $G_{B,i+j}^* > 0$ is that total valuation of the land to Party B, $(V_B + \delta^{i+1}W)$, exceeds that of the land to Party A, $V_A + \delta^{i+1}W$, modified by a weight (measured in terms of ψ , α , and β). Alternatively put, the necessary condition for Party B to arm in order to challenge Party A for the land is that the ratio of Party A's total valuation over that of Party B's is relatively *low* such that

$$\frac{V_A + \delta^{i+1}W}{V_B + \delta^{i+1}W} < 2\psi \left(\frac{\alpha}{\beta} \right) \quad (8)$$

If, instead, condition (8) fails to hold, then $G_{B,i+j}^* = 0$. Under this circumstance, there is peace. An alternative way to prevent war or create peace is through third-party intervention. Siqueira (2003) considers an interesting and prevalent intervention in terms of military subsidies provided by an intervening third-party to its ally. In our model, such military subsidies to Party A as the defender, for example, can be captured by the parameter α . This is consistent with the analysis of Siqueira (2003) in which third-party intervention is taken as exogenous. It then follows from (7b) that

$$G_{B,i+j}^* = 0 \text{ if } \alpha \leq \frac{\beta}{2\psi} \frac{V_A + \delta^{i+1}W}{V_B + \delta^{i+1}W},$$

which can be interpreted as a “deterrence strategy” contributed by the third party. A policy implication of this finding is straightforward. If Party A obtains a weapon supply from a third party at a price low enough to satisfy the above condition, other things being equal, Party A will be able to deter Party B and hence there will be no war.¹⁴

To analyze territorial dispute under the shadow of conflict, substituting $G_{A,i+j}^*$ and $G_{B,i+j}^*$ from (7a) and (7b) into Party A's probability of winning in (1) yields

$$P_{A,i+j}^* = \min \left\{ 1, k_{A,i+j} \right\}, \text{ where } k_{A,i+j} = \frac{1}{2\psi} \left(\frac{\beta}{\alpha} \right) \left[\frac{V_A + \delta^{i+1}W}{V_B + \delta^{i+1}W} \right]^{\frac{1}{2}}.$$

Based on the above analyses, we have

Proposition 1. *In the case of a territorial dispute in which Party A is a defender and Party B is its adversary, if the defending party holds more intrinsic value for the territory than its adversary ($V_A > V_B$), the likelihood that combat occurs reduces as the nature of war becomes more destructive. If physical conflict takes place, the equilibrium probability that Party A wins in a given period is increasing in Party B's cost of arming, decreasing in Party A's cost of arming, decreasing in the ratio of Party B's offensive effectiveness to Party A's defensive effectiveness, increasing in the amount by which Party A intrinsically values the land, and decreasing in the amount by which Party B intrinsically values the land.*

Proof: See A-2 in the Appendix.

It becomes apparent that in the initial period, when $(i + j) = 0$, the necessary condition under which Party B arms itself in preparation for challenging Party A is as follows:

$$\frac{V_A + \delta W}{V_B + \delta W} < 2\psi\left(\frac{\alpha}{\beta}\right).$$

Whenever Party B initially attacks its opponent, Scenarios 2-5 comprise the set of possible outcomes. In the subsequent analysis, we first discuss Scenario 2.

Scenario 2: Party A eventually deters Party B

This scenario examines the case in which the challenging party attacks the territory but at some point is deterred from further fighting without the land changing possession.

In the case where Party A does not initially deter its opponent, A chooses the optimal defense allocation ($G_{A,i+j}^*$) for each period $(i + j)$ in which it holds the land according to

equation (7a). Using (7a) and (7b), we find that $\frac{\partial G_{A,i+j}^*}{\partial \delta^{i+1}} < 0$ and $\frac{\partial G_{B,i+j}^*}{\partial \delta^{i+1}} > 0$ if and only if

$$\frac{V_A + \delta^{i+1}W}{V_B + \delta^{i+1}W} > 2. \quad (10)$$

When (10) holds, we can consider a particular outcome of the conflict during its first i periods (in which Party A controls the land). We find that Party A *increases* its defense allocation with each ensuing period in which destruction occurs (i.e., the value of δ decreases), whereas Party B *decreases* its offensive allocation. Thus, Scenario 2 is *possible* when inequality (10) is realized. It is clear from the comparative static results that, in cases where there is a

prolonged attack on a disputed land, the conflict's outcome becomes increasingly dependent upon the two parties' relative *intrinsic* valuation of the territory.

Proposition 2. *Assuming that $\delta < 1$ allows for the possibility that Party B can attack Party A and subsequently abandon all military involvement.*

Using (7a) and (7b), it is easy to verify that $\frac{\partial G_{A,i+j}^*}{\partial \delta^{i+1}} > 0$ and $\frac{\partial G_{B,i+j}^*}{\partial \delta^{i+1}} < 0$ when

$$\frac{V_A + \delta^{i+1}W}{V_B + \delta^{i+1}W} < 1. \quad (11)$$

When condition (11) obtains, Party A *decreases* its defense allocation with each ensuing round of conflict in which destruction occurs (i.e., the value of δ decreases), whereas Party B *increases* its offensive allocation. When Party B has a relatively higher total valuation for the land, the probability that Party B takes the land increases with each round in which destruction occurs. In the absence of a peace-inducing exogenous shock, Party B is less likely to be deterred. Instead, Party B will be able to take the disputed territory at some point since $G_{A,i+j}^*$ is decreasing, which lowers Party A's probability of success, and $G_{B,i+j}^*$ is increasing, which increases Party B's probability of success.

Scenario 3: Party B fights, takes the land, and deters Party A

Note that for Party B to win and hence for Scenarios 3-5 to occur, the party must fight *and* defeat A at some point as just described. After Party B takes possession of the land in period $(i + j - 1)$, Party A can choose to attack or acquiesce in period $(i + j)$. The two sides will follow the same welfare-maximizing behavior as they did when Party A held the disputed land. However, the *status* parameter ℓ is now attached to Party B, while the status parameter f is attached to Party A. That is, the contest success functions of the two parties become

$$P_{B,i+j} = \frac{\mu \ell G_{B,i+j}}{\mu \ell G_{B,i+j} + \omega f G_{A,i+j}} \quad \text{and} \quad P_{A,i+j} = \frac{\omega f G_{A,i+j}}{\omega f G_{A,i+j} + \mu \ell G_{B,i+j}}, \quad (12)$$

where ω and μ , as defined earlier, are identity parameters for the military effectiveness of Party A and Party B, respectively, the status parameter ℓ is positional effectiveness of the defender

(Party B), and the status parameter f is positional effectiveness of the attacker (Party A). The CSFs in (12) can be rewritten as

$$P_{B,i+j} = \frac{G_{B,i+j}}{G_{B,i+j} + \lambda G_{A,i+j}} \text{ and } P_{A,i+j} = \frac{\lambda G_{A,i+j}}{\lambda G_{A,i+j} + G_{B,i+j}}, \quad (12')$$

where $\lambda (= \frac{\omega f}{\mu \ell})$ represents a ratio comparing the overall (military and strategic) effectiveness of Party A in attacking the disputed territory to that of Party B in defending the disputed territory.¹⁷

We proceed to examine the third scenario, in which Party B wins and A is immediately deterred. Using backward induction, we first examine Party A's choice given that A has been defeated in period $(i + j)$. Party A's objective function is

$$U_{A,i+j+1} = E_{A,i+j} + \frac{\lambda G_{A,i+j}}{\lambda G_{A,i+j} + G_{B,i+j}} (V_A + \delta^{i+1}W) - \alpha G_{A,i+j}.$$

The Kuhn-Tucker condition for Party A is

$$\frac{\partial U_{A,i+j+1}}{\partial G_{A,i+j}} = \frac{\lambda G_{A,i+j}}{(\lambda G_{A,i+j} + G_{B,i+j})^2} (V_A + \delta^{i+1}W) - \alpha \leq 0. \quad (13)$$

If $\frac{\partial U_{A,i+j+1}}{\partial G_{A,i+j}} < 0,$

From (13), it follows that

and
$$G_{A,i+j}^{i+j} = 0 \text{ for } G_{B,i+j} \geq \sqrt{\frac{G_{B,i+j} (V_A + \delta^{i+1}W)}{\lambda \alpha}} - \frac{G_{B,i+j}}{\lambda}$$

for

Next, we discuss Party B's first defense allocation. Specifically, when Party B (now a Stackelberg leader) choose $\tilde{G}_{B,i+j} = \frac{\lambda (V_A + \delta^{i+1}W)}{\alpha}$, Party A is deterred from fighting to reclaim the land. Note that Party B's minimum defense allocation to deter Party A, $\tilde{G}_{B,i+j}$, increases with λ and hence decreases with ℓ/f .

For the case in which Party A arms such that $G_{A,i+j} > 0$, Party B's optimal choice of arming is

$$G_{B,i+j}^{**} > 0 \text{ when } \frac{\partial U_{B,i+j+1}}{\partial G_{B,i+j}} = 0 \text{ for all } G_{B,i+j}^{**} < \tilde{G}_{B,i+j}. \quad (14)$$

It is easy to verify that party B's optimal arming is

$$G_{B,i+j}^{**} = \frac{\alpha(V_B + \delta^{i+1}W)^2}{4\lambda\beta^2(V_A + \delta^{i+1}W)}. \quad (15a)$$

Substituting $G_{B,i+j}^{**}$ into Party A's reaction function in (14a) yields

$$G_{A,i+j}^{**} = \frac{(V_B + \delta^{i+1}W)[2\lambda\beta(V_A + \delta^{i+1}W) - \alpha(V_B + \delta^{i+1}W)]}{2\lambda^2\beta^2(V_A + \delta^{i+1}W)}. \quad (15b)$$

It follows from (15b) that Party A arms to challenge Party B, i.e., $G_{A,i+j}^{**} > 0$, if and only if

$$\frac{V_A + \delta^{i+1}W}{V_B + \delta^{i+1}W} > \frac{1}{2\lambda} \left(\frac{\alpha}{\beta} \right).$$

Equation (16) further implies that the necessary and sufficient condition under which party A chooses not to arm ($G_{A,i+j}^{**} = 0$), and hence there is acquiescence, is

$$\frac{V_A + \delta^{i+1}W}{V_B + \delta^{i+1}W} \leq \frac{1}{2\lambda} \left(\frac{\alpha}{\beta} \right). \quad (16)$$

Intuitively, this is the circumstance in which the total valuation of the land to Party A is “critically low” such that $V_A + \delta^{i+1}W \leq \frac{1}{2\lambda} \left(\frac{\alpha}{\beta} \right) (V_B + \delta^{i+1}W)$. Thus, if Party B defeats Party A immediately after taking the disputed territory (Scenario 3), then condition (16) holds.

Looking from the onset of the game, Scenario 3 is a possible outcome anytime Party B attempts to take power from Party A and inequality (16) is true. Additionally, if Party B defeats A and inequality (16) is true, then Scenario 3 is certain. The necessary and sufficient conditions for Scenario 3 are more likely to hold the larger is the ratio of Party A's unit cost of arming to that of Party B's (α/β), the smaller is the ratio of Party A's overall (military and strategic) effectiveness in attacking to that of Party B's in defending (λ), and the larger is the ratio of Party B's intrinsic valuation of the land compared to that of Party A's (V_B/V_A). Given the definition of λ , Scenario 3 is more likely to occur the larger the defender's (or leader's)

positional effectiveness compared to that of the challenger (or follower), other things being equal. This positional effect makes sense, as Party B must act in the role of challenger and possessor in order to take the land and effectively deter.

Scenario 4: Party B fights, takes the land, and eventually Deters Party A

Now we are in a position to examine Scenario 4, in which Party B as a challenger wins, fails to immediately deter Party A, but is able to eventually deter Party A from further fighting. The following describes briefly when Scenario 4 is possible, recognizing that Scenario 4 is essentially the opposite case to Scenario 2.

$$\text{If } \frac{V_B + \delta^h W}{V_A + \delta^h W} > \frac{1}{2\psi} \left(\frac{\beta}{\alpha} \right) \text{ for } (i+j) = 0, \dots, h+j-1, \quad (17a)$$

Party B will allocate a positive number of guns, and will have a positive probability of winning the land in each period of fighting. Let us assume Party B takes the land in period $h+j-1$.

$$\text{If } \frac{V_B + \delta^{h+1} W}{V_A + \delta^{h+1} W} < 2\lambda \left(\frac{\beta}{\alpha} \right) \text{ when } (i+j) = (h+j), \quad (17b)$$

Party B does not effectively deter Party A immediately after taking the territory.

$$\text{If } \frac{V_B + \delta^{i+1} W}{V_A + \delta^{i+1} W} > 2 \text{ where } (i+j) \geq (h+j), \quad (17c)$$

Party B moves toward deterrence after taking the land due to a similar result as that shown in inequality (10).

Let us further assume that Party B continues to hold the land during the k^{th} period ($k > h$). When both conditions (17b) and (17c) hold, the conflict moves toward a point in which

$\frac{V_B + \delta^{i+1} W}{V_A + \delta^{i+1} W} \geq 2\lambda \left(\frac{\beta}{\alpha} \right) > 2$, that is, $\frac{V_B + \delta^{i+1} W}{V_A + \delta^{i+1} W} \geq 2 \left(\frac{\omega}{\mu} \right) \left(\frac{f}{\ell} \right) \left(\frac{\beta}{\alpha} \right) > 2$. If this occurs, Party B has

evolved into a position of deterrence, and the war will end. For Scenario 4 to be possible, it

must be true that $\left(\frac{\omega}{\mu} \right) \left(\frac{\beta}{\alpha} \right) > \frac{\ell}{f} \geq 1$, indicating that, for any conflict, the possibility of Scenario 2

and that of Scenario 4 are mutually exclusive. Scenario 4 is possible only in a conflict where the initial challenger faces disadvantages in arming cost and military effectiveness but enjoys a strong advantage in intrinsic valuation. In such cases, it is possible for Party B, despite being at a tactical disadvantage, to take the land and eventually deter Party A. Driven by a comparatively

large intrinsic value for the territory, Party B will optimally devote an increasingly larger amount of resources toward the conflict after taking the territory, while Party A decreases its defensive allocation over time. If Party A fails to break Party B and retake the disputed land first, B will eventually force its rival challenger into acquiescence.

Scenario 5: subsequent conflict (including the case where war is endless)

Finally, we examine Scenario 5 in which there is subsequent conflict including the case when war is endless. In the case that Party A retakes the territory, the conflict repeats itself. The second repetition is different from the first only inasmuch as prior fighting has depreciated the economic value of the land.

There are two distinct outcomes within Scenario 5. The first outcome is when neither party can “defeat and deter” its opponent (war is endless). The second outcome is when one party “defeats and deters” its opponent (war ends).

Conditions under which war is endless

Recall that if Party A controls the territory, Party B continues to fight as long as $\frac{V_A + \delta^{i+1}W}{V_B + \delta^{i+1}W} < 2\psi\left(\frac{\alpha}{\beta}\right)$. Also, recall that if Party B controls the territory, Party A continues to fight

Party B as long as $\frac{V_A + \delta^{i+1}W}{V_B + \delta^{i+1}W} > \frac{1}{2\lambda}\left(\frac{\alpha}{\beta}\right)$. Hence, fighting continues endlessly with the territory

alternating stochastically in ownership if

$$\frac{1}{2\lambda}\left(\frac{\alpha}{\beta}\right) < \frac{V_A + \delta^{i+1}W}{V_B + \delta^{i+1}W} < 2\psi\left(\frac{\alpha}{\beta}\right)$$

or if

$$\frac{1}{2}\frac{\ell}{f} < \left(\frac{\omega}{\mu}\right)\left(\frac{\beta}{\alpha}\right)R < 2\frac{f}{\ell} \text{ for all } i \in N^*, \text{ where } R \equiv \frac{V_A + \delta^{i+1}W}{V_B + \delta^{i+1}W}. \quad (18)$$

Condition (18) requires $\ell^2 < 4f^2$ which, combined with the assumption that $\ell > f$, implies that $f^2 < \ell^2 < 4f^2$ or $f < \ell < 2f$. In other words, persistent conflict requires that the leader’s advantage to be bounded from above and below by the follower’s military capability.¹⁹ If these conditions obtain even as i approaches ∞ , then the war is endless (in absence of any exogenous shock). We observe an important result from (18) as the following proposition illustrates:

Proposition 3. *When two parties have access to different technologies militarily for challenging and defending in territorial conflict, the likelihood of never-ending conflict with stochastic alternation of land ownership reduces, all other things held equal. Nevertheless, conflict becomes more likely to persist indefinitely as the ratios of intrinsic values, relative cost of arming, relative strategic effectiveness, and relative effectiveness of military, independently approach one, ceteris paribus.*

To show Proposition 3, we note that inequality (18) reduces to $\frac{1}{2} \frac{\ell}{f} < R < 2 \frac{f}{\ell}$ if it is assumed that opposing parties have access to the same technology of conflict and face the same average costs of arming ($\omega = \mu$ and $\alpha = \beta$). In this case, each side is defined militarily only by a status parameter rather than by both an identity parameter and a status parameter. Given the inequality in (18), it becomes apparent that never-ending conflict with stochastic alternation of land ownership is *less* likely when the two sides have access to different technologies for conflict. Therefore, it is clear that the “identical technology” assumption of Gershenson and Grossman (2000), when applied generally to territorial disputes, ignores a potentially crucial factor in the outcome of a particular conflict.

Conditions under which war ends

The value of R changes with each additional round of fighting, and this can produce a situation where condition (18) no longer holds (conflict ends). The essential comparative statics are as follows:

$$\frac{\partial R}{\partial \delta^i} > 0 \text{ when } R < 1; \quad \frac{\partial R}{\partial \delta^i} = 0 \text{ when } R = 1; \quad \frac{\partial R}{\partial \delta^i} < 0 \text{ when } R > 1.$$

If R changes over time to the extent that inequality (18) is no longer satisfied, the conflict will end. Moreover, due to R 's monotonic movement over the course of a conflict, only the party that places more total value on the territory is capable of defeating and deterring its opponent once a conflict has reached Scenario 5. Therefore, a “seemingly” endless conflict can end even in the absence of exogenous shock. We thus have

Proposition 4. *If conflict over a territorial dispute is to end, it may end more quickly (and will not end less quickly) as the nature of war becomes more destructive.*

This proposition becomes apparent if we look again at inequality (18). When $V_A \neq V_B$, it is easy to show that the value for $\frac{\partial R}{\partial \delta^i}$ deviates farther from zero as δ increases. In other words, in a highly destructive conflict, relative land valuation changes more quickly. This fact can cause highly destructive conflicts to be resolved more quickly, all other things held equal. However, a speedier conclusion to the conflict can occur through an exogenous shock. For example, if Party A is suddenly able to obtain free weapons from an ally, this could potentially end the conflict.

3. CONCLUDING REMARKS

Social scientists have observed that territorial disputes are the primary cause of war and that they can vary considerably in terms of duration and outcome. In view of these observations, we develop a stylized game-theoretic model to characterize explicitly the outcome of a territorial dispute. Our model concludes that the roots of variation in a conflict's duration and outcome lie in how the two parties compare with respect to land valuation, military effectiveness, and cost of arming; as well as the degree of positional advantage, if any, the territory gives to its possessor and the rate at which the land's economic value depreciates. We conclude that land dispute between two similar parties will persist indefinitely, given that the controlling party does not enjoy a stark positional advantage. Thus, conflict is more likely to end when opposing parties have access to different technologies for challenging political dominance, *ceteris paribus*. We also find that, if a conflict is to end, a high rate of physical destruction may cause it to end more quickly (and will never cause it to end less quickly). In yet another circumstance, the model reveals that, as the nature of war becomes more destructive, the likelihood of a peaceful outcome, in which the territory's initial possessor deters the challenging party, increases if the initial possessor holds more intrinsic value for the land. Lastly, assuming that war is (exogenously) destructive allows for the possibility that a challenging party can attack a defending party's territory and subsequently abandon all military involvement. Thus, both the degree to which access to technology differs across party and the (exogenous) level of destruction associated with the fighting, among other factors, help determine the duration and outcome of a conflict.

Following Siqueira (2003), our model harbors policy implications for third-party intervention for preventing war. But the limitations of this paper, and hence possible extensions, should also be mentioned. First, the paper does not feature an endogenous mechanism by which the two parties might peacefully negotiate. Second, our analysis focuses on strategic interaction between rival parties in a myopic period-to-period framework without using a simultaneous multiple-period decision-making approach. Interesting issues in such a multiple-period analysis include, among others, the optimal timing of launching a surprise attack and the conditions under which a territory's defender can effectively deter a challenger. Another possibility is to endogenize the role of a third party or an international institution in resolving territorial disputes. Lastly, one could consider a model in which foregone trade is treated as an opportunity cost of territorial dispute. In such a framework, one might examine conditions under which trade can help to deter fighting. Certainly, as European countries have opened markets since World War II, this opportunity cost has risen dramatically.

Appendix A - Footnotes for the “Fate of Disputed Territories.”

1. Gershenson and Grossman (2000) develop an interesting model to characterize the nature of *civil* conflict.

2. In another example, when Argentina successfully took the Falkland Islands in 1982, this brief victory had no implications for relative military spending effectiveness, as the two parties did not have access to the same technologies for challenging and defending political dominance.

3. By exogenous destruction, we mean that level of damage in a conflict does not depend on level of guns.

4. The term “peaceful outcome” means that there is no fighting. In other words, the territory’s initial possessor is able to effectively deter the challenging party from attacking.

5. Gershenson and Grossman’s model does not allow for the possibility of this outcome.

6. As in Gershenson and Grossman (2000), Garfinkel and Skaperdas (2000) and Grossman (2004), we consider a pure strategy equilibrium concept without using a mixed strategy approach. Garfinkel and Skaperdas further indicate that conflict is more likely to emerge when a party has the perception that the future matters.

7. For analyses of the nature of various forms of contest success functions, see, e.g., Tullock (1980), Hirshleifer (1989), and Skaperdas (1996).

8. The terms “military good” and “gun” are used interchangeably in this paper.

9. Note that N^* is defined as the set of non-negative integers.

10. Note that, as other researchers before us, we take intrinsic and economic land valuation as given. As stated by Gershenson and Grossman (2000), valuations “incorporate the possibility that one group might be willing and able to decrease the value of political dominance to the other group.” They explain that this alteration may be achieved through promises from one group to the other, for instance.

11. U.S. help in the Spanish-American War both reduced unit arming cost and increased military effectiveness for the Cuban rebels (see, e.g., Pratt, 1995; and Convers, Alexander, and Levinson 1995; Stoner and Luis 2005).

12. We follow Grossman and Kim (1995), Gershenson and Grossman (2000), Gershenson (2002), and Stauvermann (2002) in utilizing a Stackelberg, or sequential-move, game framework in which the defender leads. In particular, Gershenson (2002) defends this structure by assuming that the incumbent's institutional framework is relatively rigid; therefore, defensive allocations constitute a commitment on the part of the incumbent. The advantage of this assumption is that it allows for the analysis of a deterrent strategy on the part of the defender.

13. A-1 in the Appendix presents detailed derivations of the results for Scenario 1.

14. We thank an anonymous referee for pointing out the model's policy implications for peace through third-party intervention. The referee further indicates that cost parameters α and β can be changed through arms boycotts, the presence of United Nations peacekeeping forces, and "no blood/conflict diamonds" publicity campaigns (for the cases of Angola, the Democratic Republic Congo, and Sierra Leone).

15. Condition (10) indicates that Party A's intrinsic and economic value must be twice that of Party B's. This finding is consistent with the result of Gershenson and Grossman (2000), despite of their assumption that $\delta = 0$. See A-3 in the Appendix for a detailed derivation of condition (10).

16. The sign of $\frac{\partial G_{B,i+j}^*}{\partial \delta^{i+1}}$ is ambiguous over the range $1 \leq \frac{V_A + \delta^{i+1}W}{V_B + \delta^{i+1}W} \leq 2$ as the model is currently defined.

17. Note that $\lambda(= \frac{\omega f}{\mu \ell})$ is not the inverse of $\psi(= \frac{\mu f}{\omega \ell})$, which implies that Scenario 3 is *not* the reciprocal of Scenario 1. This is because we consider not only a status parameter that captures relative military effectiveness of the parties, but also an identity parameter that characterizes relative strategic effectiveness of the parties.

18. See A-4 in the Appendix for a detailed derivation of the levels of arming by both Party A and Party B.

19. We thank an anonymous referee for pointing out this important requirement for the case of persistent conflict.

Appendix B - Derivations for “Fate of Disputed Territories”

A-1. In the initial period $t=0$, Party B as the Stackelberg follower chooses $G_{B,0}$ to maximize

$$U_{B,0} = E_{B,0} \frac{\psi G_{A,0} + \psi G_{B,0}}{\beta G_{A,0} + \psi G_{B,0}} (V_B + \delta W) - \beta G_{B,0}$$

The Kuhn-Tucker condition for Party B is

$$\frac{\partial U_{B,0}}{\partial G_{B,0}} = \frac{(V_A + \delta^{i+1}W)}{(G_{A,i+j} + \psi G_{B,i+j})^2} [(G_{A,i+j} + \psi G_{B,i+j}) - G_{A,i+j} (1 + \psi \frac{\partial G_{B,i+j}}{\partial G_{A,i+j}})] - \alpha = 0$$

if $G_{B,0} = 0$

$$U_{A,i+j+1} = E_{A,i+j} + \frac{G_{A,i+j}}{G_{A,i+j} + \psi G_{B,i+j}} (V_A + \delta^{i+1}W) - \alpha G_{A,i+j} \quad (a.1)$$

It follows that

$$\frac{\partial U_{B,i+j+1}}{\partial G_{B,i+j}} = \frac{\psi G_{A,0} (V_B + \delta W) + \delta^{i+1}W}{(G_{A,i+j} + \psi G_{B,i+j})^2} - \beta = 0$$

when $\frac{\psi G_{A,0}}{(G_{A,0})^2} (V_B + \delta W) < \beta$

Thus the minimum defense allocation of Party A to deter Party B from arming and attacking is

$$G_{B,0} > 0$$

If Party B chooses to arm such that $G_{B,0} > 0$, then B has a positive probability of defeating the

initial leader of the territory. Party B’s optimal level of arming in period $t=0$ in which $G_{B,0} > 0$ is positive should satisfy the following first-order condition (FOC):

$$G_{A,0} > \frac{\psi (V_B + \delta W)}{\beta} \quad (a.2)$$

$$\frac{\partial U_{B,0}}{\partial G_{B,0}} < 0,$$

Solving for $G_{B,0}$ yields Party B’s reaction function of arming:

$$G_{B,0} = 0 \quad (a.3)$$

Party A as the Stackelberg leader chooses $G_{A,0}$ to maximize

$$U_{A,0}$$

where $G_{B,0}$ is given by the reaction function in (a.3). Party A’s FOC is

$$\frac{\partial U_{A,0}}{\partial G_{A,0}} = 0 \quad (a.4)$$

Substituting (a.3) into (a.4), we solve for Party A’s optimal level of arming as follows:

(a.5)

Substituting $2\psi\alpha(V_B + \delta^{i+1}W) > \beta(V_A + \delta^{i+1}W)$ into Party B's reaction function in (a.3), after arranging terms, yields

(a.6)

It follows from (a.6) that the necessary condition for Party B to arm itself for possible attack is

$$\frac{\partial G_{A,i+j}^*}{\partial \delta^{i+1}} = \frac{2\psi\alpha(V_B + \delta^{i+1}W) - \beta(V_A + \delta^{i+1}W)}{2(V_B + \delta^{i+1}W)^2} > 0$$

To determine Party A's probability of winning, we substitute $G_{A,i+j}^* > 0$ and from (a.5) and (a.6) into A's CSF in (1) to obtain

$$\text{where } \frac{\partial P_{A,i+j}^*}{\partial \psi} < 0,$$

A-2. Taking the derivative of

$$G_{B,i+j}^* > 0 \text{ yields } \frac{\partial P_{A,i+j}^*}{\partial \psi} > 0, \text{ if } \frac{\partial V_{A,i+j}}{\partial \delta^{i+1}W} > 2.$$

It is straightforward to derive the following derivatives:

$$\text{and } \frac{\partial P_{A,i+j}^*}{\partial V_B} < 0.$$

A-3. Taking the derivative of in (a.5) with respect to yields $\frac{V_A + \delta^{i+1}W}{V_B + \delta^{i+1}W} < 2\psi\left(\frac{\alpha}{\beta}\right)$.

Next, taking the derivative of in (a.6) with respect to yields

It follows that and if and only if

A-4. The FOC for Party A (as a Stackelberg follower) to arm is

$$\frac{\partial U_{B,i+j+1}}{\partial G_{B,i+j}} = \frac{(V_B + \delta^{i+1}W)}{(G_{B,i+j} + \lambda G_{A,i+j})^2} [(G_{B,i+j} + \lambda G_{A,i+j} - G_{B,i,j})(1 + \lambda \frac{\partial G_{A,i+j}}{\partial G_{B,i,j}})] - \beta = 0.$$

Solving for $G_{B,i+j}^*$ yields party A's reaction function:

$$G_{B,i+j}^* = \frac{(V_B + \delta^{i+1}W)[2\lambda\beta(V_A + \delta^{i+1}W) + \beta(V_B + \delta^{i+1}W)]}{G_{B,i+j} + 2\lambda\beta(V_A + \delta^{i+1}W)} \quad (a.7)$$

$$\frac{\partial U_{A,i+j+1}}{\partial G_{A,i+j}} = \frac{(V_A + \delta^{i+1}W)}{(G_{B,i+j} + \lambda G_{A,i+j})^2} (G_{B,i+j} + \lambda G_{A,i+j}) - \alpha = 0.$$

The objective function of Party B (as a Stackelberg leader) is

$$G_{A,i+j}^{**} > 0$$

where $G_{B,i+j}^*$ is given by Party A's reaction function in (a.7). The FOC for Party B is

$$(a.8)$$

Substituting (a.7) into (a.8), we solve for Party B's optimal level of arming as follows: $\alpha > \frac{V_A + \delta^{i+1}W}{V_B + \delta^{i+1}W} > \frac{1}{2}(\frac{\omega}{f})(\frac{1}{\beta})$.

Substituting back into Party A's reaction function in (a.7) yields

Given that we have if and only if

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